A Single 6146 Amplifier

The photographs of Figs. 6-64, 6-67, and 6-68, show views of an amplifier using a single 6146. With the built-in supply shown, it can be operated at an imput of about 70 watts, or up to 90 watts with a 750-volt supply. The circuit is shown in Fig. 6-65. The input circuit is a conventional parallel-tuned tank with link coupling. However, the inductor is made up in two sections to avoid the inefficiencies of shorting turns on a single large coil in switching to the higher frequencies. A separate link coil is used with each of the two grid coils.

A pi-section tank circuit is used in the output. The amplifier is keyed in the cathode circuit. The single milliammeter may be switched to read either grid current or cathode current. The 150-ohm series resistor and the 22-ohm parallel resistor form a meter shunt that increases the full-scale reading to 250 ma. when checking cathode current.

Construction

The layout of components is shown in the photographs. In the box, the tube socket should be placed far enough back on the chassis so that the tube will clear the meter. C_7 is placed to the rear to space it about an inch from the tube. It is mounted on an aluminum bracket so as to bring its shaft up to the proper level. A panel bearing is coupled to the shaft.

RFC_3, C_8 and C_9 are mounted on an insulated terminal strip to the left of the tube socket. The flexible plate lead to the 6146 is connected to RFC_3 and C_8 at this strip. The v.h.f. parasitic suppressor L_5 is connected between this lead and the plate connector.

To the rear of the tube socket is another strip with two insulated terminals. A piece of No. 16 wire about 2 inches long is soldered vertically to each of the insulated terminals. Then a piece of "spaghetti" is slid over each of the wires. The capacitance between these wires provides the capacitance shown in Fig. 6-65 as C_3. This capacitor is the neutralizing capacitor to stabilize the amplifier.

A crystal socket is used as the input connector J_1, as shown in Fig. 6-66. If preferred, a coaxial

Fig. 6-64—The base for the 6146 amplifier is a 11 × 7 × 3-inch aluminum chassis. A 6 × 6 × 6-inch aluminum box encloses the amplifier tube and its output circuit. S_2 is to the right of the meter. Below, from left to right, are controls for S_3, C_7 and C_4. On the chassis, from left to right, are the power-supply switches (see Fig. 6-66), J_1 (see text) and J_3, and controls for C_1 and S_1. Ventilation holes are drilled in the cover in the area above the tube, and along the sides of the box, near the bottom. The power-supply diagram is shown in Fig. 6-66.

A 6146 Amplifier

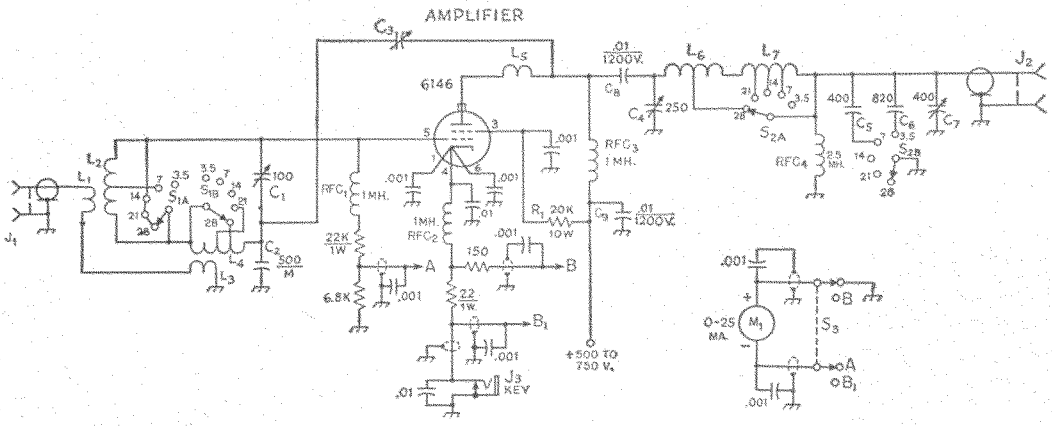


Fig. 6-65—Circuit of the 6146 band-switching amplifier. All capacitances less than 0.001 μf. are in $\mu\mu$f. All unmarked bypasses are disk ceramic. All resistors are ½ watt unless otherwise specified. Filament and meter wiring should be shielded as indicated.

C_1—100-$\mu\mu$f. variable (Hammarlund MC-100-S).
C_2—470-$\mu\mu$f. mica.
C_3—Neutralizing capacitor (see text).
C_4—250-$\mu\mu$f. variable (Hammarlund MC-250-S).
C_5—400-$\mu\mu$f. tub. ceramic (Centralab DC-401).
C_6—820-$\mu\mu$f. tub. ceramic (Centralab D6-821).
C_7—400-$\mu\mu$f. variable capacitor (broadcast replacement type).
C_8—C_9—Disk ceramic.
J_1—See text.
J_2—Coaxial receptacle (SO-239).
J_3—Close-circuit key jack.
L_1-L_7—See coil data opposite.
M_1—0-25-ma. d.c. milliammeter, 2½-inch square (Shurite).
RFC_1, RFC_4—1- or 2.5-mh. (National R-50).
RFC_2, RFC_3—1- or 2.5-mh. (National R-100).
S_1, S_2—Double-pole 6-position rotary switch (Centralab PA-2003).

COIL DATA

The coils L_1L_2 are made from a single length of B & W Miniductor stock. Unwind 8 turns from the support bars and using side cutters, snip off the projecting bars. Snip the unwound piece of wire off about one inch from the coil stock. Next count off 13 turns and bend the 13th turn in toward the axis of the coil and cut the wire at this point. At the cut, unwind ½ turn from each coil. This leaves two coils on the same support bars. Unwind ½ turn at the end of the large coil. The 12-turn coil is L_1 and the 42-turn coil is L_2. Similar procedure is followed in making L_3L_4.

L_1 — 12 turns of No. 24, 1-inch diam, 32 turns per inch (B & W 3016).
L_2 — 42 turns of No. 24, 1-inch diam., 32 turns per inch (B & W 3016).
40-meter tap is made at 25th turn counting from junction of L_2L_4.
L_3 — 4 turns of No. 20, ⅝-inch diam., 16 turns per inch (B & W 3007).
L_4 — 13 turns of No. 20, ⅝-inch diam., 16 turns per inch (B & W 3007).
20-meter tap is made at junction of L_2L_4.
15-meter tap is made 4½ turns from junction of L_2L_4.
10-meter tap is made 7½ turns from junction of L_2L_4.
L_5 — 4 turns of No. 14, ¼-inch diam., turns spaced wire diam.
L_6 — 5½ turns of No. 12, 1-inch diam., turns spaced so that coil is 1-inch long.
10-meter tap is made 1½ turns from junction of L_6L_7.
L_7 — 17½ turns of No. 16, 2-inch diam., 10 turns per inch (B & W 3907-1).
15-meter tap is made 2 turns from junction of L_6L_7.
20-meter tap is made 5 turns from junction of L_6L_7.
40-meter tap is made 9 turns from junction of L_6L_7.

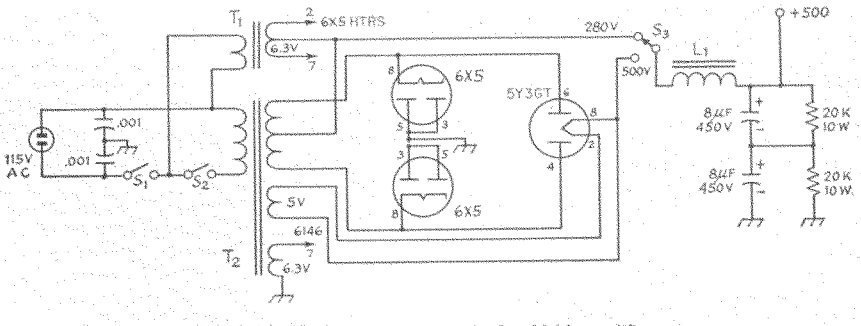


Fig. 6-66—Economy power supply for 6146 amplifier.

L_4—10.5 henrys, 110 ma., 225 ohms.
S_3—1-pole 6-position (2 used) wafer switch, non-shorting (Centralab 1401).
S_4—1-pole 6-position (2 used) steatite wafer switch, nonshorting (Centralab 2501).
T_1—Filament transformer, 6.3 volt, 1.2 amperes.
T_2—Power transformer, 360-0-360 volts, 120 ma., 6.3 volts 3.5 amperes, 5 volts 3 amperes (Stancor PC8410).

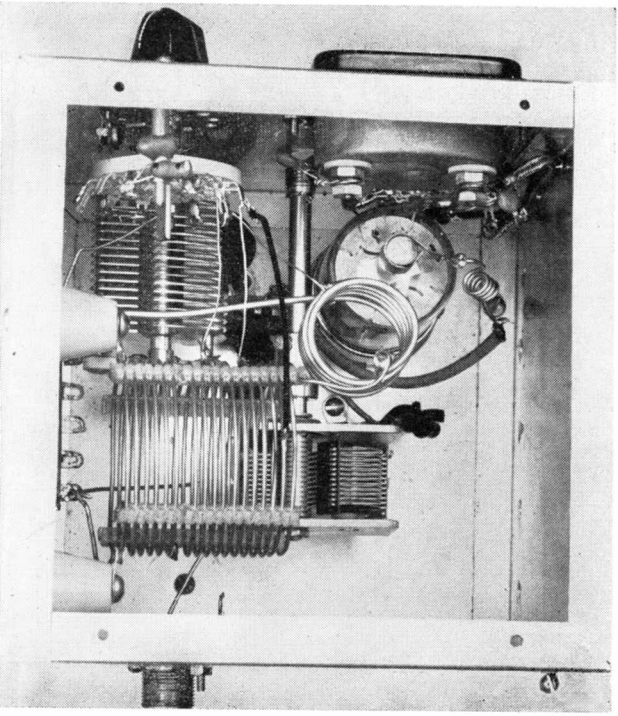


Fig. 6-67—This view shows the arrangement of components in the box. L_7 is supported by two lugs soldered to the end turn and fastened to 1-inch cone insulators centered 1¾ inches down from the top of the box. L_6 is supported at right angles to L_7 by soldering its top end to the inner end of L_7. The twisted insulated wires forming C_3 appear immediately in front of C_7 near the center.

receptacle similar to J_2 may be mounted at the rear.

Adjustment

The amplifier requires a driver delivering at least 2 watts. The usual v.f.o. will not drive it without an intermediate amplifier, such as a 6AQ5. However, most crystal oscillators operating at 300 volts should be adequate.

The first step in the adjustment is to neutralize the amplifier. The high-voltage line to the plate and screen should be disconnected temporarily at the high voltage terminal in Fig. 6-65. The exciter should be tuned up on the highest-frequency band available.

With the heater voltage only applied to the 6146, excitation should be applied, and C_1 adjusted to give maximum grid current. Then, with S_2 set to the same band as the grid circuit, and C_7 set at maximum capacitance, C_4 should be turned through its range. Unless the amplifier is neutralized, there should be a kick in the grid current at some point within the range of C_4. When this point has been found, the two insulated wires representing C_3 should be twisted together a bit at a time until the grid-current kick is brought to a minimum.

The high-voltage connection to the plate and screen may now be replaced. A 60-watt lamp may be connected across J_2 to serve as a dummy load during testing. With power and excitation applied, and C_7 at maximum capacitance, adjust C_4 for a dip in cathode current. Then reduce C_7 a little at a time, each time readjusting C_4 for the dip in cathode current. As C_7 is reduced, the dip in cathode current should become less pronounced and the load lamp should increase in brilliance. Continue these alternate adjustments until the cathode current at the point of dip is maximum, but do not allow it to exceed 150 ma.

The output circuit is designed to feed 50- or 70-ohm matched antenna systems. For other antenna systems, an antenna tuner should be used between the amplifier and the antenna. With an antenna replacing the dummy load, the adjustment procedure should be similar.

(Originally described in *QST*, August, 1956.)

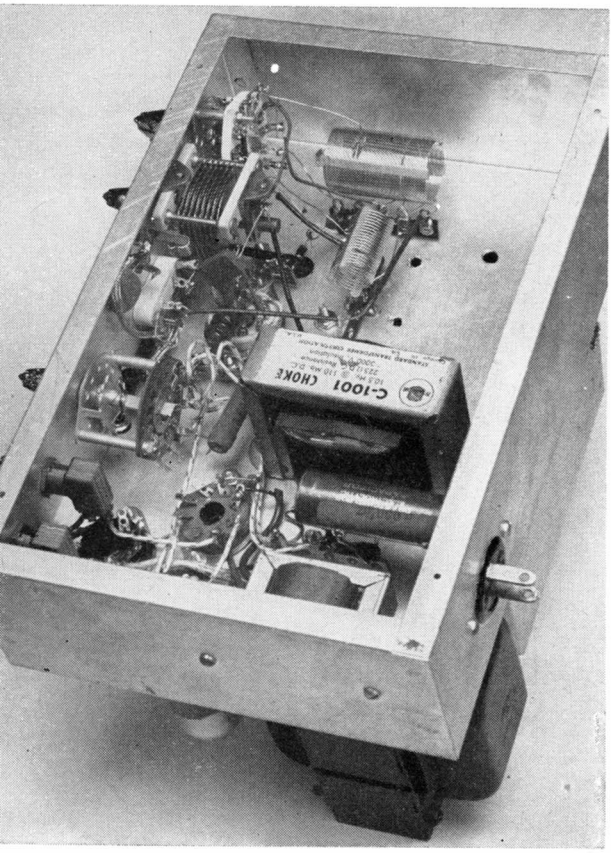


Fig. 6-68—The grid tank coils L_2 and L_4 are supported on soldering-lug strips to the rear of S_1 and C_1. Power-supply filter components are grouped in the lower right-hand corner.

An All-Purpose 813 Amplifier

Figs. 6-69 through 6-72 show the circuit and photographs of an 813 amplifier designed for c.w., a.m., or s.s.b. operation. Provision has been made for convenient changing from one mode to another as well as to any of the bands from 80 through 10 meters.

The circuit is shown in 6-70. A turret-type grid circuit is used and the output circuit is a pi network designed to work into coax cable. The inductor is the rotary-type variable. Provision for neutralizing is included. R_1 is a parasitic suppressor.

For Class C c.w. or phone operation, S_4 is open. The 90 volts of fixed bias, furnished by a small bias supply and regulated by the VR90, is augmented by a drop of about 50 volts across the grid-leak resistor R_2 at a normal grid current of 15 ma. This brings the total bias to 140 volts. With S_4 closed, the grid leak is short-circuited and the 90 volts of fixed bias alone remains for AB_2 s.s.b. operation. (An advantage in AB_2 for c.w. operation is that it preserves the keying characteristics of the exciter better than with Class C operation.) R_3 should be adjusted so that the VR90 just ignites with no excitation.

Screen voltage is regulated at 750 volts by a string of five 0A2s for s.s.b. operation. When the grid drive is increased for Class C operation, the screen current increases, increasing the drop across the screen resistor R_5, and the screen voltage falls to 400. The regulators then lose control and the amplifier is ready for plate-screen modulation.

The screen is protected against excessive input, should the load or plate voltage be removed, by the overload relay K_1. The tripping point is set at 40 ma. by the variable shunt resistor R_4. If the relay trips, current through R_6 will hold the screen circuit open until plate voltage is removed. One meter, M_1, measures cathode current, while the other meter, M_2, may be switched to read either grid current or screen current.

Forced-air ventilation is always advisable for a medium- or high-power amplifier if it is buttoned up tight to suppress TVI. A surplus 100 c.f.m. blower does the job more than adequately.

Construction

The amplifier is built on a 13 × 17 × 4-inch aluminum chassis fastened to a standard 12¾ × 19-inch rack panel. The r.f. output portion is enclosed in a 12½ × 13 × 8½-inch box made of aluminum angle and sheet. The VR tubes, relay, blower and meters are mounted external to the box.

The grid tank-circuit components are mounted underneath the chassis and are shielded with a 5 × 7 × 3-inch aluminum box. A standard chassis of these dimensions might be substituted. The bias and filament transformers are in a second box measuring 6 by 3 by 3 inches. This type of construction, together with the use of shielded wire for all power circuits, was followed to reduce TVI to a minimum. Each wire was bypassed at both ends with 0.001-μf. ceramic disk capacitors. L_4 can be adjusted to series resonate with the 600-$\mu\mu$f. capacitor at the frequency of the most troublesome channel. A Bud low-pass filter completes the TVI treatment. As a result, the amplifier is completely free of TVI on all channels even in most fringe areas.

Adjustment

In the pi network, the output capacitors are fixed. However, the adjustment of the network is similar to that of the more conventional arrangement using a variable portion of the output capacitance. The only difference is that the "fine" loading adjustment is done with the variable inductor.

The inductor is fitted with a Groth turns counter, making it easy to return to the proper

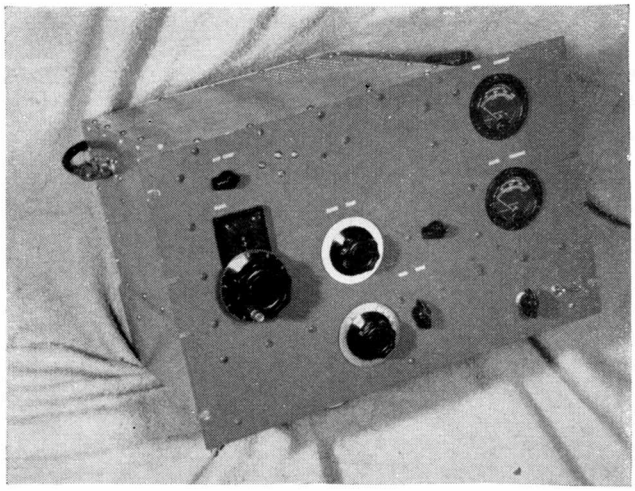


Fig. 6-69—W4SUD's all-purpose 813 amplifier. The output-capacitor switch (coarse loading) is above the turns counter for the variable inductor. Dials near the center are for the plate tank capacitor C_4 (above) and the grid tank capacitor C_1 (below). To the right of the dials are the controls for the plate padder switch S_3 (above) and the grid band switch S_1 (below). The toggle switch below the meters is the mode switch S_4 with the meter switch S_5 to the left. Ventilating holes are drilled in the cover in the area above the tube. The output connector is on the left-hand wall of the shielding box.

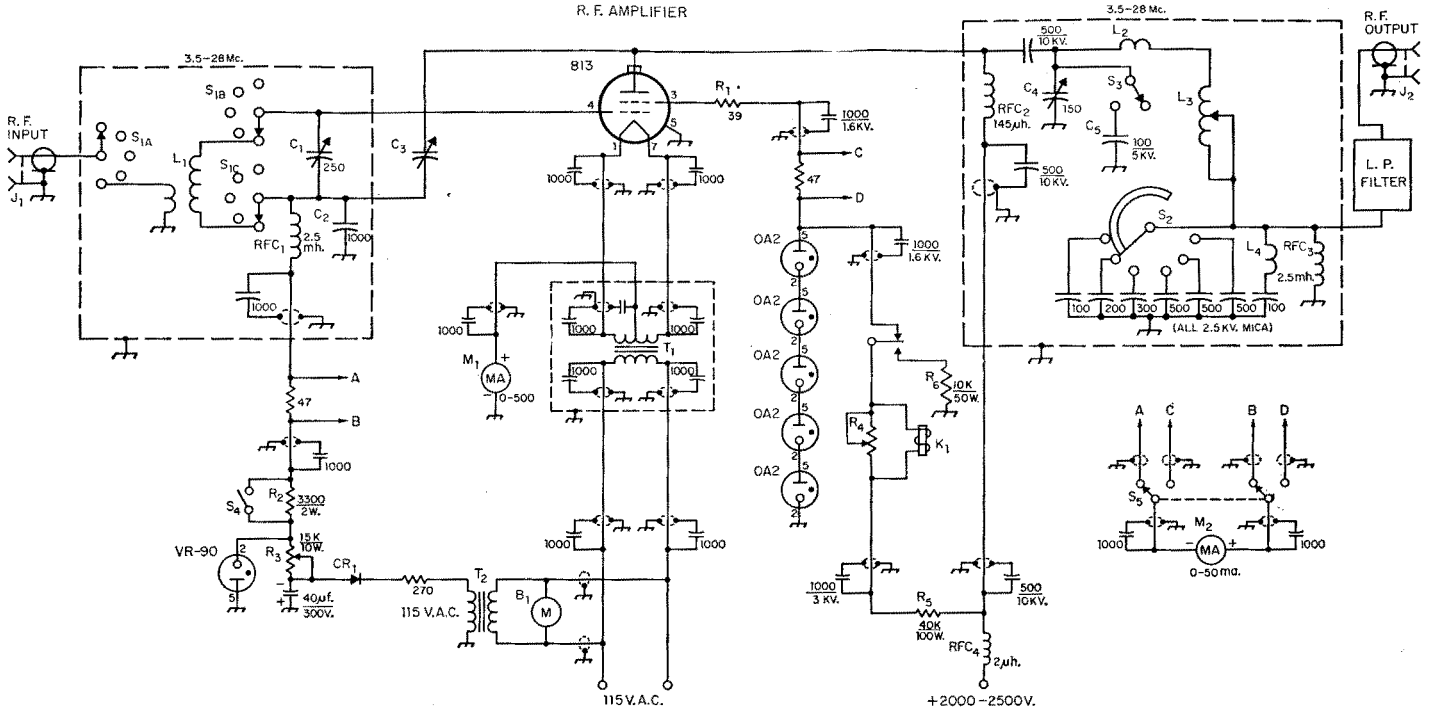


Fig. 6-70—Circuit of the all-purpose 813 amplifier. Unless otherwise designated, capacitances are in μμf. Capacitors marked with polarity are electrolytic. Other capacitors not listed below should be ceramic. Resistances are in ohms.

B_1—Ventilating blower, 100 c.f.m. (surplus).
C_1—250-μμf. variable (Hammarlund MC-250-M).
C_2—1000-μμf. mica.
C_3—Neutralizing capacitor, 10 μμf. maximum (Johnson 159-250).
C_4—150-μμf. 6000-volt variable (Johnson 153-12).
C_5—100-μμf. 5000-volt fixed capacitor (surplus vacuum Amperex VC-100, or two 200-μμf. 5000-volt micas in series).
CR_1—130-volt 50-ma. selenium rectifier.
J_1, J_2—Coaxial receptacle (SO-239).
K_1—Screen overload relay, 2500 ohms, 7 ma. (Potter & Brumfield KCP5).
L_1—3.5 Mc.—32 turns No. 20, 1-inch diam., 2 inches long, 5-turn link (B&W 3015 or Airdux 816).
—7 Mc.—18 turns No. 20, ¾-inch diam., 1⅛ inches long, 3-turn link (B&W 3011 or Airdux 616).
—14 Mc.—10 turns No. 18, ⅝-inch diam., 1¼ inches long, 2-turn link (B&W 3006 or Airdux 508).
—21 Mc.—7 turns No. 18, ⅝-inch diam., ⅞ inch long, 1-turn link (B&W 3006 or Airdux 508).
—28 Mc.—5 turns No. 18, ⅝-inch diam., ⅝ inch long, 1-turn link (B&W 3006 or Airdux 508).
L_2—3 turns 3/16-inch copper tubing, 1-inch diam., 1¾ inches long.
L_3—15-μh. variable inductor (B&W 3852).
L_4—See text.
M_1, M_2—3½-inch d.c. milliammeter.
R_1—39 ohms, ½-watt carbon.
R_2—3300 ohms, 2 watts.
R_3—15,000 ohms, 10 watts with slider.
R_4—2000-ohm 4-watt variable resistor (Mallory M2-MPK).
RFC_1, RFC_3—2.5-mh. r.f. choke (National R-50 or similar).
RFC_2—Plate r.f. choke (National R-175-A).
RFC_4—V.h.f. choke (National R-60).
S_1—Rotary switch: 3 wafers, 3 poles, 11 positions per pole, 5 positions used (Centralab PA-0 wafers, PA-301 index).
S_2—Rotary switch: single pole, 10 positions, progressively shorting, 6 positions used (Centralab PA-2042).
S_3—Rotary switch: s.p.s.t., ceramic (antenna link switch from BC-375 tuning unit, or Communications Products Model 65).
S_4—S.p.s.t. toggle switch.
S_5—D.p.d.t. rotary switch (Centralab 1405).
T_1—Filament transformer: 10 volts, 5 amp. (Thordarson 21F18).
T_2—Bias transformer: 120 volts, 50 ma.; 6.3 volts, 2 amp., filament winding not used; could be used for pilot light (Merit P-3045).

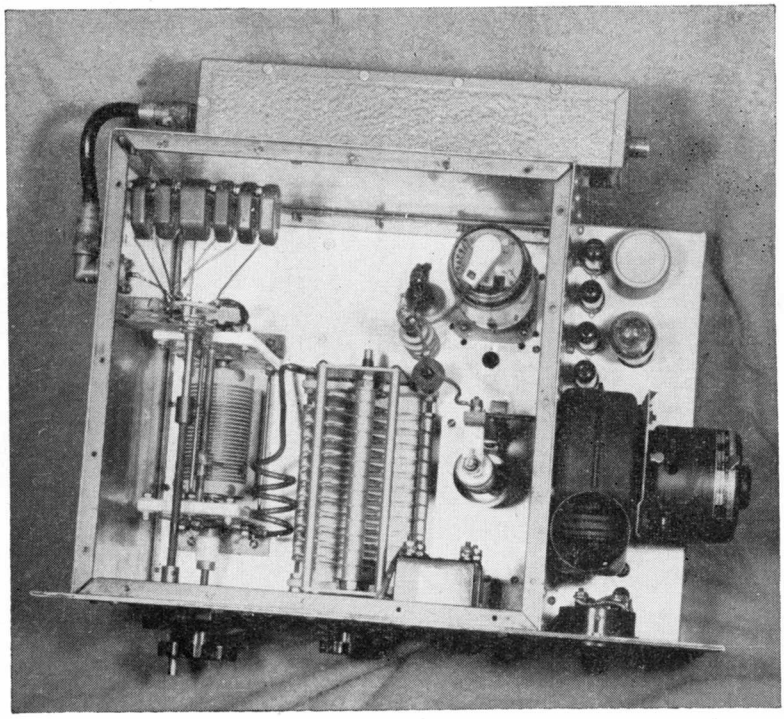


Fig. 6-71—This view shows the placement of components on the chassis. The 813 socket is mounted on spacers over a large clearance hole in the chassis. The several mica output capacitors are assembled in a stack on a threaded rod fastened to the left-hand wall of the shielding box. The neutralizing capacitor and the 80-meter plate padder are to the right of the tank capacitor. To the right of the box are the five 0A2s (the front one hidden), the screen overload relay and the VR90, the blower and meters.

setting for each band. Until the settings for each band have been found, S_3 should be turned so that all of the output capacitance is in circuit. The inductor should be set near maximum for 80, and approximately half maximum for 40. On the higher-frequency bands, the inductor should be set so that the circuit resonates with the tank capacitor near minimum capacitance. Loading should increase as the output capacitance is decreased. A change in output capacitance requires a readjustment of C_4 for resonance. When the loading is near the desired point, final adjustment can be made by altering the inductance slightly.

A 20-A or similar exciter is well suited as a driver for this amplifier on all modes. The 813 runs cool at 500 watts input on a.m. and c.w. and at 1000 watts p.e.p. on s.s.b. (Originally described in *QST* for August, 1958.)

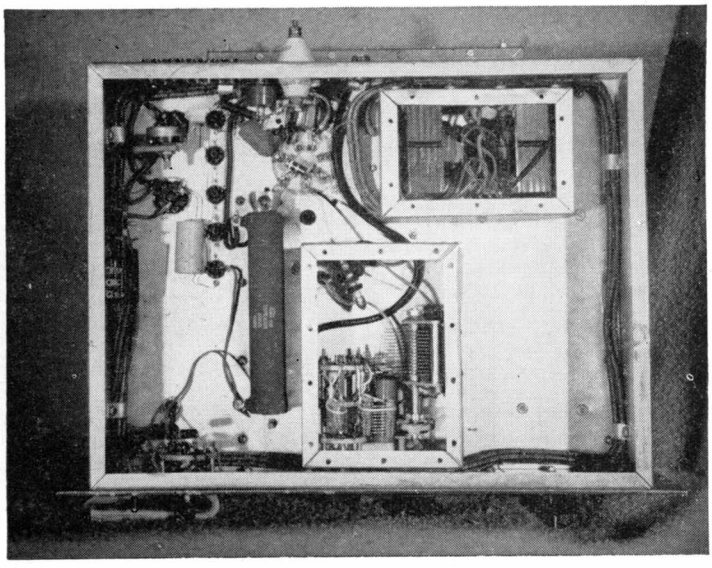


Fig. 6-72—Bottom view of the all-purpose 813 amplifier. The grid tank-circuit components within dashed lines in Fig. 6-70 are enclosed in the box at lower center. Input links are wound over ground ends of grid coils. Filament and bias transformers are in the second box. The large resistor to the left of the grid box is the screen resistor. The variable resistor in the upper left-hand corner is the relay shunt R_4. The selenium bias rectifier is fastened against the left-hand wall of the chassis

6 – HIGH-FREQUENCY TRANSMITTERS

A Medium-Power Tetrode Amplifier

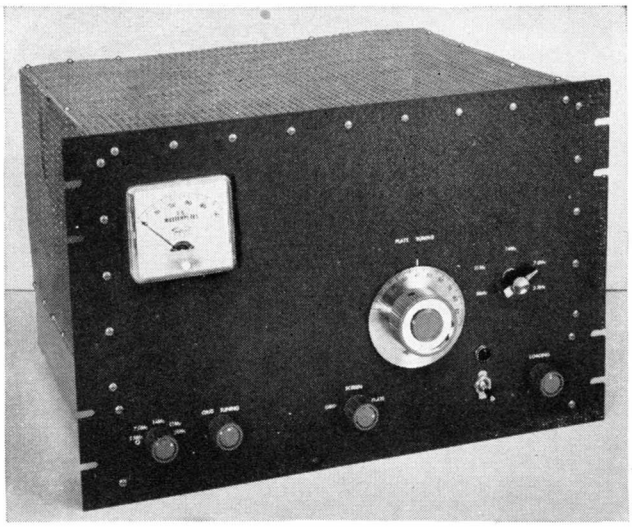


Fig. 6-73—This medium-power tetrode amplifier is assembled on a 17 × 12 × 3-inch aluminum chassis with a 19 × 12¼-inch rack panel. Controls along the bottom of the panel are for the grid band switch, grid tuning capacitor, meter switch, a.c. power, and pi-network loading capacitor. Above are the controls for the plate tank capacitor and plate band switch. The sides and back of the shielding enclosure are a single piece of Reynolds perforated aluminum sheet "wrapped" around the chassis. A 1-inch lip is bent along the three top edges so that the top cover can be fastened on with sheet-metal screws.

Figs. 6-73 through 6-76 show photographs and circuit diagram of an amplifier using an RCA 7094 tetrode that will handle up to 500 watts input on c.w. or 330 watts with plate-screen modulation. Construction has been simplified by the use of manufactured subassemblies — a Harrington Electronics GP-50 multiband grid tank and a B & W type 851 bandswitching pi-network inductor. The amplifier is neutralized by the capacitive-bridge method. R_1 and L_5 are adjusted to suppress v.h.f. parasitic oscillation. The single milliammeter M_1 may be switched to read either grid or plate current. The shunt R_2 multiplies the original 50-ma. scale by 10, giving readings up to 500 ma. when the meter switch S_3 is in the plate-current position. Forced-air ventilation is provided by a small blower B_1. Shielded wire is used in all power circuits and terminal leads are bypassed for v.h.f. as they enter the chassis.

Construction

The plate blocking capacitor is threaded onto one of the plate tank-capacitor stator rods. Plate-circuit leads are made of ½-inch copper strip. Screen and filament bypasses are connected directly between the tube-socket terminals and the perforated sheet. Each of the three screen terminals is bypassed with a 1000-μf. 1600-volt disk ceramic capacitor. The grid-tank unit is spaced from the front wall of the chassis on 1-inch pillar insulators to provide space for an insulating shaft coupling.

Along the rear wall of the chassis are the coax

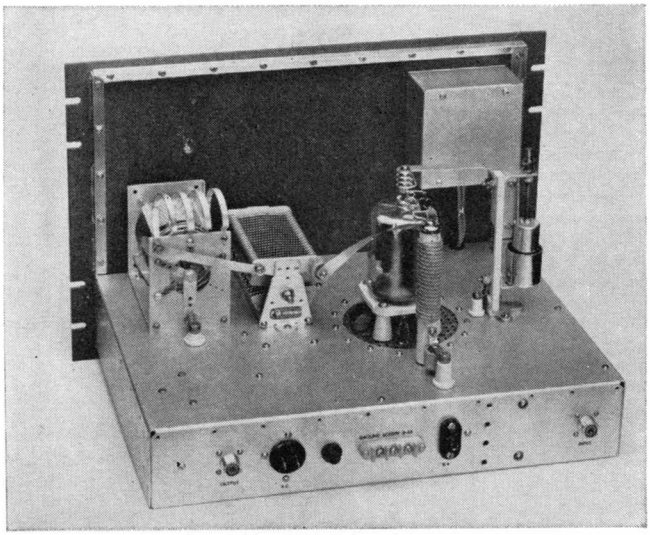


Fig. 6-74—Rear view of the medium-power amplifier. The shafts of the plate band switch and plate tuning capacitor are 2¾ and 6¼ inches from the left-hand end of the chassis in this view. A ventilating hole somewhat larger than the tube socket (829-B type) is centered 6½ inches from the right-hand end of the chassis and 6 inches from the rear. A piece of perforated aluminum covers the hole and supports the tube socket mounted on 1-inch ceramic cones. Feed-through insulators carry connections to the bottom terminals of the plate tank-coil unit, the plate r.f. choke and the neutralizing capacitor. The meter is enclosed in a 4 × 4 × 2-inch aluminum box.

Medium-Power Tetrode Amplifier

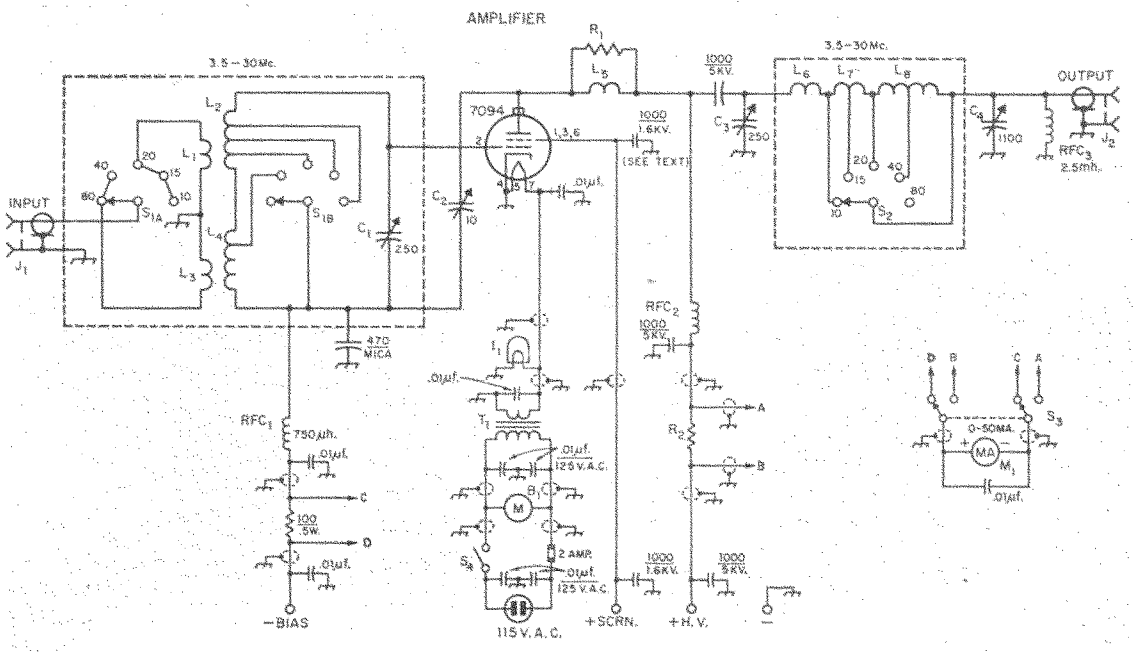


Fig. 6-75—Circuit of the 7094 amplifier. Unless specified otherwise, capacitances are in $\mu\mu$f. All fixed capacitors rated at less than 5 kv. are disk ceramic. The 5-kv. capacitors are TV-type ceramics (Centralab 858). Dashed lines in grid circuit enclose components of Harrington GP-50 multiband tank unit. Those in the plate circuit enclose components of the B & W 851 pi-network inductor.

B_1—Blower (Allied Radio Cat. No. 72P715).
C_1—250-$\mu\mu$f. midget variable (special).
C_2—Neutralizing capacitor—11 $\mu\mu$f. max. (Johnson N125).
C_3—250-$\mu\mu$f. 3000-volt variable (Johnson 250E30).
C_4—1100-$\mu\mu$f. variable—triple-gang broadcast replacement type, 365 $\mu\mu$f. (or more) per section, sections connected in parallel.
I_1—6.3-volt dial lamp.
J_1, J_2—Coax receptacle (SO-239).
L_1—2 turns No. 16, 1 inch diam., over ground end of L_2.
L_2—14 turns No. 16, ¾ inch diam., 2 inches long.
L_3—3 turns No. 16, 1 inch diam., over ground end of L_4.
L_4—38 turns No. 22, ¾ inch diam., 1½ inches long.
L_5—3 turns No. 12, ⅜ inch diam., 1 inch long.
L_6—4 turns ⅜ × ⅜-inch copper strip, 1⅜ inches diameter, 2½ inches long.
L_7—4¼ turns No. 8, 2½ inches diam., 1¾ inches long, tapped at 3 turns from the L_8 end.
L_8—9½ turns No. 12, 2½ inches diam., 1½ inches long, tapped at 6 turns from the output end (see text).
Note: L_7 and L_8 are mounted close together on the same axis; L_6 is mounted at right angles.
M_1—D.c. milliammeter, 0–50-ma. scale—3⅜-inch rectangular (Triplett Model 327-PL).
R_1—Three 150-ohm 1-watt carbon resistors in parallel.
R_2—Approx. 32 turns No. 24 on a ¼-inch diam. form (see measurements section for method of adjustment).
RFC_1—750-μh. r.f. choke (National R-33).
RFC_2—Plate r.f. choke 120μh (Raypar RL-101).
RFC_3—2.5-mh. r.f. choke (National R-50).
S_1—Two-wafer 5-position ceramic rotary switch.
S_2—Special heavy-duty 5-position rotary switch (component of B & W inductor unit).
T_1—Filament transformer: 6.3 volts, 3.5 amps. minimum (Thordarson 21F11).

output connector, a.c. power connector, fuse, screen-voltage, bias and ground terminals, high-voltage connector (Millen) and the coax input connector. Strips of ½-inch aluminum angle fastened to the panel provide a means of fastening the shielding enclosure to the panel. Paint should be removed where the angle rests against the panel so that there will be good electrical contact between the two.

Preliminary Adjustment

To maintain a tank Q of 10 at 4 and 7.3 Mc., 4 turns should be removed or shorted out at the front end of the B&W unit, and the 40-meter tap should be moved one turn toward the rear. (For operation at less than maximum ICAS ratings, see pi-network charts earlier in this section.)

Before applying excitation, the amplifier should be checked for v.h.f. parasitic oscillation as described earlier in this section. A resistor of about 20,000 ohms should be connected between the bias terminal and ground. Full plate voltage may be applied, but the screen should be operated from an adjustable 50,000-ohm 50-watt series resistor connected to the plate supply. The grid band switch should be turned to the 10-meter position and the plate switch to the 80-meter position. With the meter switched to read plate current, the screen resistance should be reduced until the plate power input is about 100 watts. The meter should then be switched to read grid current and the recommended procedure followed. The objective is to suppress the parasitic oscillation with the smallest possible coil to keep the parasitic-circuit

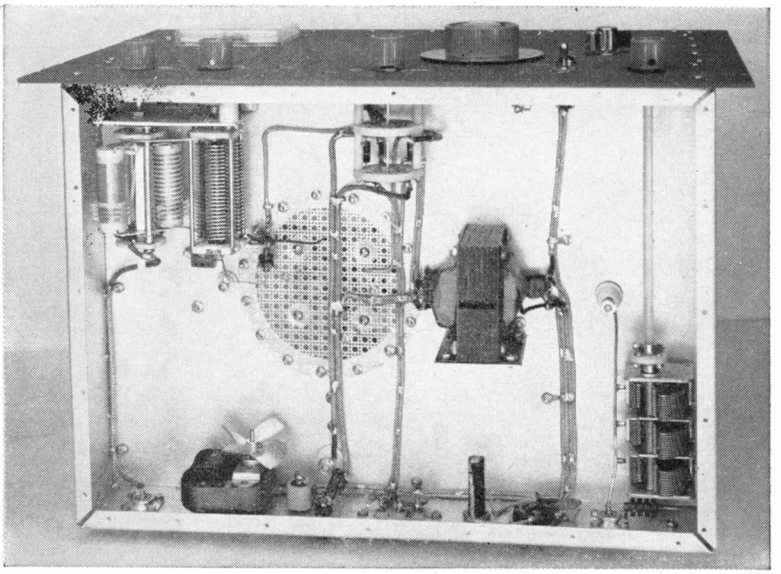


Fig. 6-76—Bottom view of the 7094 amplifier. The grid-tank assembly in the upper left-hand corner and the output loading capacitor in the lower right-hand corner are placed so that the shaft of the latter and the shaft of the grid band switch are 1½ inches from the ends of the chassis. Spacers between the chassis and the output capacitor bring its shaft level with those of the grid-tank unit. The meter switch is at the center. The filament transformer is mounted on an aluminum bracket. The ventilating fan is bolted against the rear wall of the chassis.

resonant frequency between the two v.h.f. TV bands. If oscillation is detected, additional loading resistors should be tried first. If this does not work, another turn should be added to the coil, or the turns squeezed closer together. With the parasitic coil described, the resonant frequency of the circuit is about 100 megacycles.

Neutralizing

Neutralizing should be done with excitation applied to produce rated grid current. The input and output circuits should be tuned to the same frequency. Plate and screen voltages should be disconnected at the transmitter terminals. The neutralizing capacitor should then be adjusted until a point is found where there is no change in grid current as the plate tank circuit is tuned through resonance. The output capacitor should be set at maximum capacitance for this check. After plate and screen voltages have been applied and the amplifier loaded, the neutralizing capacitor should be given a final adjustment to the point where minimum plate current and maximum grid and screen currents occur simultaneously.

Power Supply

Maximum ICAS ratings on the 7094 are 1500 volts, 330 ma. on c.w., 1500 volts, 200 ma. (max.) Class AB_1 s.s.b., and 1200 volts, 275 ma. for a.m. phone. However, the tube will work well at plate voltages down to at least 700 volts, provided appropriate values are used in the pi network as mentioned previously. The recommended screen voltage is 400 for all classes of operation at screen currents up to 30 ma., depending on the type of operation. Therefore a regulated screen voltage can be obtained using a pair of 0D3s and one 0C3 in series. If screen voltage is obtained from the plate supply, an adjustable 100-watt 75,000-ohm series resistor should be used and the value adjusted to obtain the desired operating plate current after initial tuning adjustments have been made.

Biasing

A fixed biasing voltage of 50 is required for s.s.b. operation. Batteries should last indefinitely. The biasing voltage may also be obtained from a voltage divider across a VR tube with suitable series resistor. A biasing voltage of 130 is recommended for plate-modulated Class C service, and 100 volts for c.w. operation. Recommended grid current is 5 ma. If the screen is operated from a fixed-voltage source, a source regulated by an 0A3 should provide plate-current cut off. The balance of the required operating bias may be obtained from a grid leak (5000 ohms for c.w. or 11,000 ohms for phone). In case the screen is supplied through a dropping resistor from the plate supply, fixed biasing voltages of 100 for c.w. or 130 for phone (no grid leak) should provide reasonable protection for the tube in case of failure of excitation.

The rated driving power is 5 watts, easily furnished by a 2E26 without pushing it. Existing transmitters using a 6L6, 6146 or 807 in the final may be used if provision is made for controlling the output of these units by adjustment of screen voltage.

650-Watt Amplifier

A Compact 650-Watt Amplifier

Compactness in the high-power amplifier shown in Figs. 6-77 through 6-82 is achieved through the use of germanium rectifiers in the power supply and tubes of the radial-beam type. When driven by an exciter delivering about 30 watts output, the amplifier runs at about 650 watts input and gives an output of about 400 watts on c.w. or p.e.p. s.s.b. It covers 80 through 10 meters by means of band switching and has a fixed 50-ohm output impedance.

Two 4X250B tubes operating Class AB_2 are used in a grounded-cathode circuit (see Fig. 6-78). No grid tuning is used, since an exciter of the size mentioned will drive the grids directly across the 110-ohm resistance. L_1 is a series peaking coil to increase the drive on 10 meters. A parallel-tuned tank with fixed-link output coupling is used in the plate circuit. This system has the advantage that series plate feed can be used, and no large output capacitance is needed. Tuning is straightforward and the coupling, once adjusted holds over a wide frequency range.

The link circuit is grounded through a removable jumper at the output connector, so that a balanced load can be fed if desired.

The small 15-$\mu\mu$f. capacitor (CRL Type 850), from the plates to ground, provides a short path for harmonic currents and keeps them out of the output coil. On the 3.5- to 4-Mc. range a fixed 100-$\mu\mu$f. capacitor is connected across the coil, so that a proper L-to-C ratio can be maintained at 4 Mc. When switched out of the circuit, the coil and fixed capacitor resonate around 5 Mc., which is sufficiently removed from any of the other ranges to avoid any difficulty.

The 10-ohm resistor in the B + lead serves as a fuse in case of a shorted tube or other fault that might endanger the power supply.

Power Supply

The plate supply uses two voltage doublers in series; see Fig. 6-81. Two 325-volt windings on T_2 feed strings of germanium rectifiers in full-wave voltage-doubler connections. Each doubler capacitance is 160 μf., made up of two parallel 80-μf. 450-volt cartridge type units with cardboard sleeves. The chassis is lined with insulating material under the C_5 and C_6 capacitors, since their outer cans run as high as +1300 volts. The ripple is around 3 per cent r.m.s., and the regulation from no load to full load is about 15 per cent. Sixteen cells are used. Each group of four cells in one side of a voltage doubler has two 560 K resistors connected across pairs of cells to equalize the reverse voltage drop. Other 560 K resistors are connected as bleeders only as a safety measure, since no bleeders are needed for proper circuit operation. But even with the bleeders, the capacitors can retain a charge for several minutes, so be careful!

Grid bias is furnished by a 75-volt winding on T_1, a half-wave rectifier and an 80-μf. capacitor. About −90 volts is developed across C_9 and applied to the tubes during stand-by periods. The operating bias is adjustable from −30 to −60 volts by R_3.

Screen voltage is taken from the +375-volt point of the plate supply (junction C_7 and C_8). It is dropped through the 6BF5 regulator to deliver a low-impedance output adjustable from about 250 to 325 volts at up to 75 ma. Since this type of regulator will not handle reverse current, bleeder R_2 (Fig. 6-78) is provided to offset no-signal negative screen current to the 4X250Bs and make the screen meter read on scale.

When in operating condition, the "reference" voltage for the screen regulator is the −90 volt bias supply. In stand-by condition the reference is switched down to the tap on R_3, thus reducing the screen voltage from its nominal +300 or so to a lower value. This action, together with the increased grid bias, insures that the 4X250Bs

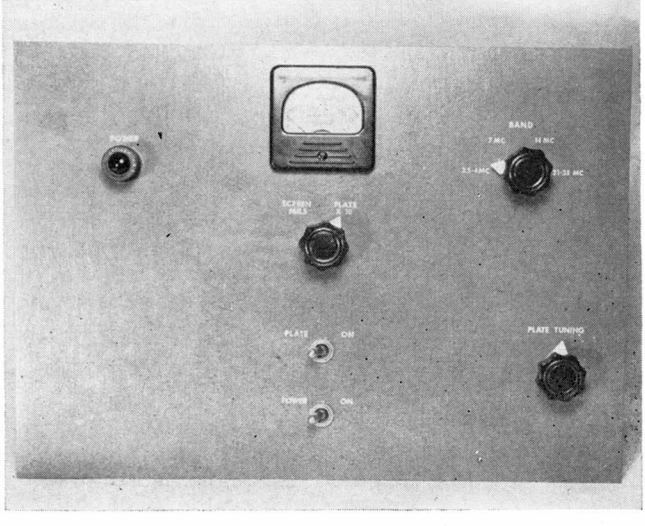


Fig. 6-77—The panel of this 650-watt amplifier built by W9LZY measures only 10 by 14 inches. Below the meter are the meter switch, high-voltage switch and filament/bias switch. To the right are controls for the band switch (above) and the tank capacitor (below).

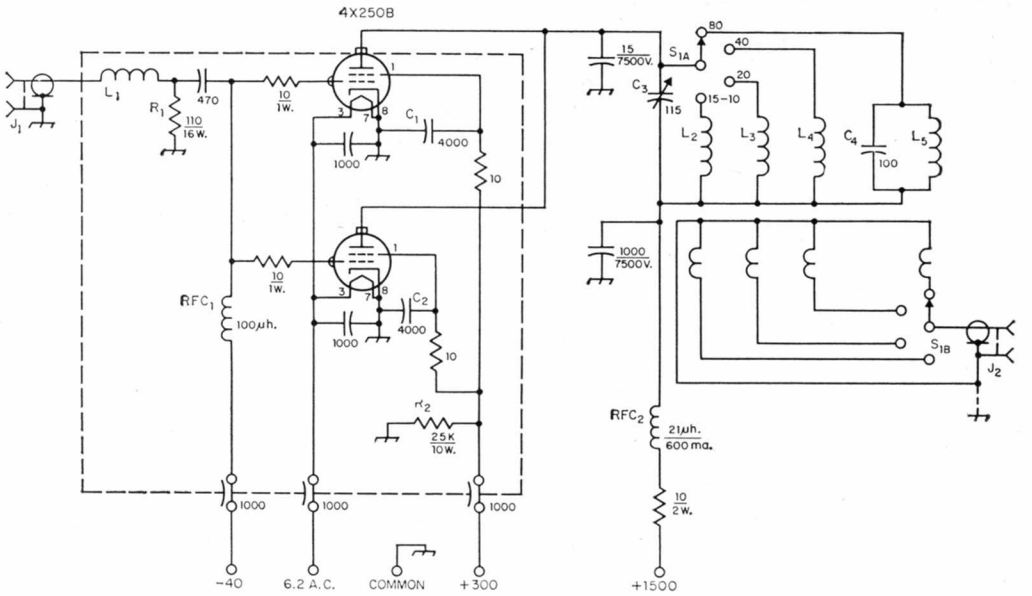


Fig. 6-78—Circuit diagram of the r.f. portion of the amplifier. Unless otherwise indicated, capacitances are in μμf., resistances are in ohms, resistors are ½ watt. The 1000-μμf. plate bypass is a CRL Type 858-S; the 1000-μμf. feed-through capacitors are 500-volt ceramic.

C_1, C_2—Four 1000-μμf. 500-volt disk ceramic capacitors in parallel.

C_3—115-μμf. variable, 2000-volt spacing. See text.

C_4—Two 25-μμf. NPO ceramic and one 50-μμf. N750 ceramic in parallel, 7500-volt rating.

J_1—UG-291/U BNC panel jack (Amphenol 31-001).

J_2—SO-239 UHF panel jack (Amphenol 83-1R).

L_1—6 turns No. 20, ⅜-inch diam., ½ inch long.

L_2—4½ turns ⅛-inch copper tubing, 1¼ inches long, 1⅛-inch diam. Link is 3 turns No. 16 wire, ¾ inch long, ¾-inch diam

L_3—6 turns ⅛-inch copper tubing, 1½ inch long, 1⅝-inch diam. Link is 2 turns No. 12, ½ inch long, 1⅛-inch diam.

L_4—8½ turns No. 12, 1⅛ inches long, 2⅛-inch diam. Link is 3 turns No. 12, ⅝ inch long, 1½-inch diam.

L_5—Two coils, see text. Outer is 10 turns No. 12, 1⅜ inches long, 2⅛-inch diam. Inner coil is 6½ turns No. 12, ¾ inch long, 1¾-inch diam., inside plate end of outer coil. Link is 4 turns No. 12, ½ inch long, 1½-inch diam.

RFC_1—100-μh. r.f. choke (National R-33-4).

RFC_2—21-μh. 600-ma. r. f. choke (Ohmite Z-28).

draw no current in standby condition. In operation the grid, screen, and plate voltages all tend to vary in proportion to line-voltage changes.

The screen current is measured by switching the 0-75 milliammeter across 22 ohms in the lead to the screen-voltage regulator. The resistor has negligible shunting effect. For measuring plate current the meter is switched across a low resistance R_6, connected between the two sections of the plate supply. R_5 was adjusted for

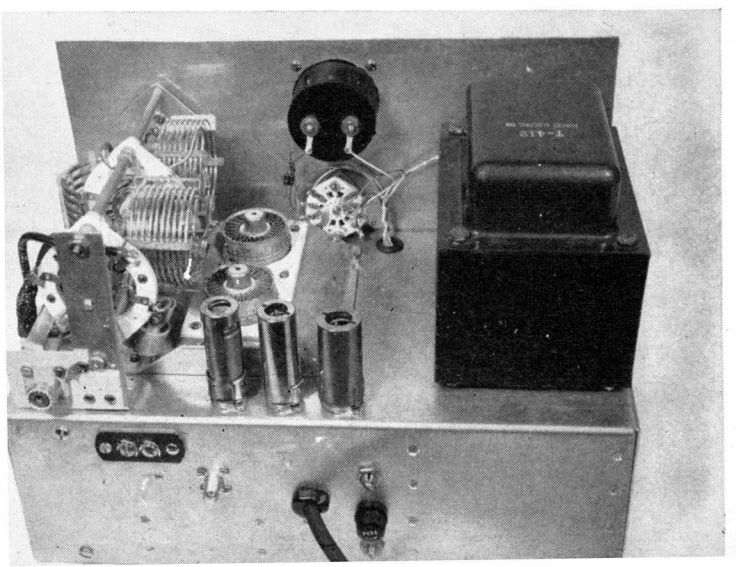


Fig. 6-79—Rear view of the 650-watt amplifier showing mounting of the 4X250Bs and the plate transformer. Shields in the foreground enclose voltage-regulator tubes and a relay. The shaft protruding from the rear edge of the chassis operates the bias potentiometer.

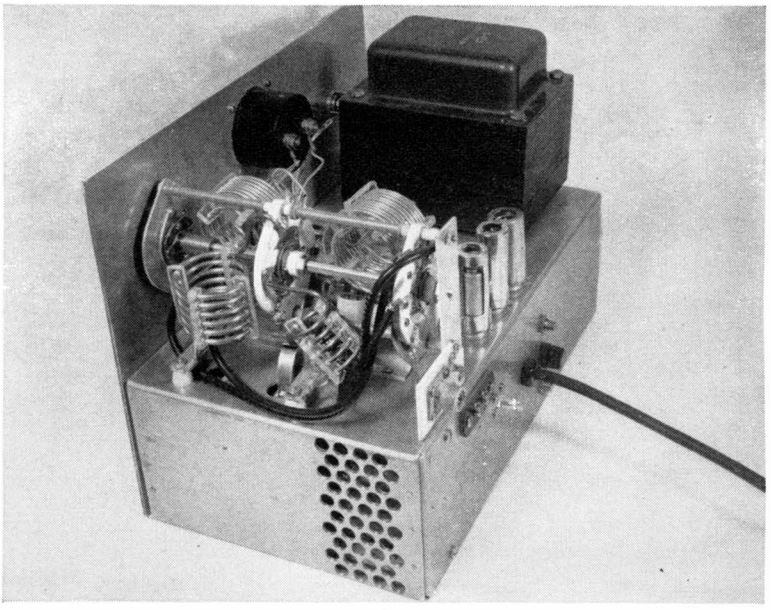


Fig. 6-80—Side view of the 4X250B amplifier showing mounting of the band switch and tank coils. The chassis is perforated for ventilation.

full-scale meter reading at 750 ma. There is a maximum of 425 volts between switch contacts and 850 volts from contacts to ground.

The stand-by relay K_1 is one that plugs into a 7-pin miniature socket. It operates from 115 volts a.c. and a half-wave power supply. The input is brought out to two terminals on the rear of the chassis, where connection is made across the antenna relay coil.

Construction

The amplifier is built on an 8 × 14-inch chassis with a 10 × 14-inch panel. The chassis is 4½ inches deep, to provide space for the filter capacitors and cooling fan underneath. As can be seen by studying the photographs, the plate power supply occupies the left end of the chassis, and the r.f. circuits take most of the remaining space. The heater and bias supply is stowed under the right rear corner of the chassis behind the plate tuning capacitor. The screen regulator and stand-by relay are at the rear of the chassis in the center.

The controls are few and simple. The band switch has four positions, for the 80-, 40-, 20- and 15- and 10-meter bands. Other controls are the plate tuning capacitor, plate-current/screen-current meter switch, power and plate voltage switches.

The plate tank capacitor is one from a BC-375 tuning unit, mounted under the chassis on four ceramic feed-through bushings. (Any other capacitor of equivalent rating, such as the Johnson 155-4 may be substituted.) Four holes were drilled and tapped in the ¼-inch square frame rods on the right-hand side of the capacitor, and 6-32 threaded rod was screwed into the holes and passed through the insulators. The four screws project above the insulators at the top of the chassis, where the B+ ends of the plate coils connect to them via copper strips. An insulated shaft extension goes through the panel to the tuning knob.

The wire from each coil was wrapped around a pipe of suitable diameter. Four Plexiglass strips were drilled with clearance holes at the desired spacing, then the coil wire was fed through the holes. The 80-meter coil was made with two concentric sections in series to get enough inductance into the available space. The 80- and 40-meter links were also threaded through strips, while the 20- and 10-meter links are self-supporting. All links are a push fit inside the insulating strips of their respective coils, and are held with a drop or two of cement after adjustment.

The two band-switch wafers are each single-pole, 4-position, 60-degree throw (Communications Products Co., Type 86). A 60-degree index-and-shaft assembly from an Oak Type H switch was used. The rest of the switch was made up from 6-32 threaded brass rod, ¼-inch o.d. tubing, 1/16-inch aluminum sheet, and miscellaneous ceramic spacers and fiber washers from junked rotary switches.

The front wafer switches the plate coils. The links are connected to the rear wafer through RG-58/U cable, except the 80-meter link which goes direct. The cold sides of all links are soldered to a strip of copper running around the wafer, supported by 2-56 screws through the unused holes between contacts. The u.h.f.-type output connector is mounted on a strip of bakelite fastened to the rear switch bracket; its shell is grounded through a couple of solder lugs shown. T_2 weighs about twenty pounds; the chassis should be at least 0.08-inch aluminum to be strong enough to carry it.

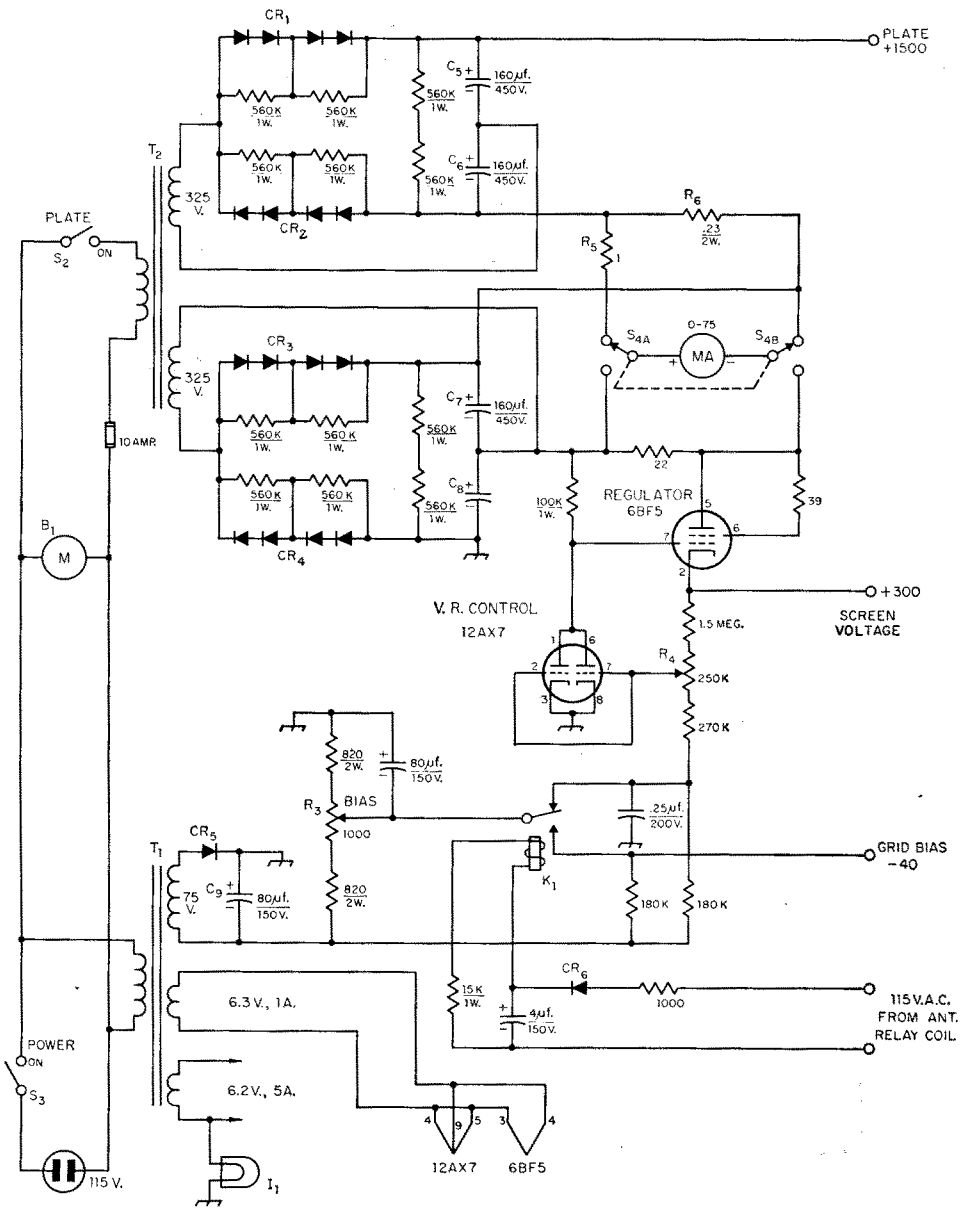


Fig. 6-81—Circuit of the power supply. Unless otherwise indicated, resistances are in ohms, resistors are ½ watt.

B_1—3250-r.p.m. motor with 4-inch fan blade (Rotron* 92-AS motor).

C_5 C_6, C_7, C_8—Two 80-μf. electrolytics in parallel (Sprague TVA-1716). Insulate as described in text.

CR_1—CR_4—Four 500-ma. 300-volt peak inverse (1N153 or equiv.).

CR_5—100-ma. 380-volt peak inverse.

CR_6—65-ma. 380-volt peak inverse (Federal 1002A).

I_1—150-ma. 6-8 volts (GE No. 47).

K_1—5000-ohm coil, 4 ma. pull-in (Terado Series 600 or equivalent).

R_3—2-watt linear potentiometer (Ohmite CU-1021).

R_4—2-watt linear potentiometer (Ohmite CU-2541).

S_2, S_3—15-amp. 125-volt toggle (Cutler-Hammer 7501-K13).

S_4—Two-pole 2-throw 60-degree throw ceramic rotary switch, non-shorting. See text.

T_1—6.2 volts at 5.5 amp., 6.3 volts at 1 amp., 75 volts at 100 ma. (Forest Electric Co.** T-423).

T_2—Two-secondaries, each 325 volts, 1 amp. (Forest** T-412).

*Rotron Mfg. Co., 7 Schoonmaker Lane, Woodstock, New York.

**Forest Electric Co., 7216 Circle Rd., Forest Park, Ill.

650-Watt Amplifier

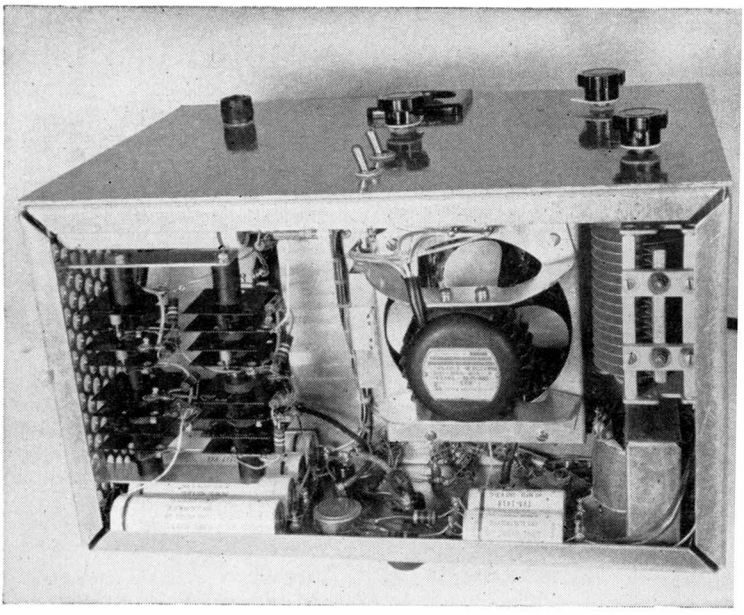


Fig. 6-82—This bottom view show the ventilating fan, tank capacitor, rectifier stacks and filter capacitors.

A bottom cover and a perforated-metal shield over the top, sides and rear should be added, for safety as well as TVI-proofing. An opening should be cut above the r.f. tubes and covered with hardware cloth.

Cooling

Each 4X250B tube requires at least 3.6 cubic feet of air per minute through the anode cooler. The base also requires some air. The tube is ordinarily mounted in an Eimac "air-system" socket so that the air flows first over the base, then through the anode cooler. This leads to a fairly large pressure drop, which is ordinarily considered to require a centrifugal blower. Since a blower of this type requires considerable space, the design has been altered to permit the use of a fan. Only the insulating rings and contacts from Eimac sockets are used, mounted by the cathode tabs in oversized holes in the chassis. Many small holes are drilled in the chassis to provide additional air passage. A small aluminum housing above the chassis directs all the air through the anode coolers. It comes to within ¼ inch of the anode coolers. The opening is closed by a piece of Fiberglas-base plastic fitting on top. It comes to within 1/16 inch of the tubes, so that a small amount of the air flows around the outside of the coolers.

All of the left end and part of the right end of the chassis are perforated by ⅜-inch holes. The air drawn in by the fan passes over the plate rectifier fins and past the heater transformer. The whole air path is direct and free from large obstructions and sharp bends.

The fan is a 4-inch blade driven by a Rotron Mfg. Co. Type 92-AS motor at 3250 r.p.m. It is mounted in a hole 4⅛ inches in diameter in the grid housing, with about ⅛ of the blade thickness projecting into the housing. The motor is a capacitor-run type. The 1-μf. 600-volt phasing capacitor mounts on the side of the grid housing. The motor, housing and capacitor can be removed as a unit, leaving only the front and rear walls of the housing in place.

Under the conditions described, the pressure *vs.* flow curves of the fan and of the tubes indicate that somewhere around 10 c.f.m. of air is delivered. This is entirely ample for the pair of 4X250Bs. Since the only major source of heat is the tubes, and since this heat is quickly removed by the air, the whole amplifier runs at a satisfactorily low temperature.

Operation

For Class AB_2 operation, the screen voltage is set at 300 volts, and the grid bias at a point (about −40 volts) where the tubes draw 150 ma. without drive. When operating and fully loaded, full output from an HT-30 or similar exciter should swing the plate current to approximately 400 ma.

The various links are of approximately the right inductance to couple to a 50-ohm load. They must be quite tightly coupled to their plate coils. When properly positioned with a 50-ohm load connected, the plate current dips 10 or 15 ma. as the plate capacitor is tuned through resonance with r.f. drive applied. Once adjusted, these links are left alone. The antenna is tuned with the aid of an s.w.r. bridge to present a 50-ohm load to the amplifier. The amplifier should not be operated without a suitable load

Operation is now very simple. The heaters are warmed up for at least 30 seconds. With the plate power switch *off*, the band switch is set to the proper range. The exciter is tuned up to give c.w. output. (Not more than 40 volts r.m.s.) The plate power is turned on and the plate capacitor tuned to the plate current dip, or to maximum indicated output if a Micromatch is being used. The exciter is then set to give the type of output desired.

(Originally described in *QST* for Sept. 1958.)

4-250-A's in a 1-Kw. Final

The amplifier shown in the accompanying photographs uses two 4-250As in parallel and covers 3.5 to 28 Mc. with complete band-switching. The output circuit is a pi network designed for working into reasonably well-matched 52- to 75-ohm coaxial lines. The amplifier can handle a kilowatt input in Class C operation on either phone or c.w. without pushing the tubes to their limits. It can also be operated as a linear amplifier for single side band.

The various components are mounted on a 17 × 13 × 4-inch aluminum chassis attached to a standard 19-inch relay rack panel 15¾-inches high. The above-chassis section is enclosed in a 11½-inch high shield made from 1/16-inch sheet aluminum. An aluminum bottom plate completes the below-chassis shielding. Enclosing the amplifier in this way, plus the use of shielded wire and filters in the supply leads, takes care of the harmonic TVI question.

The 4-250As are cooled by forcing air into the chassis and thence up past the tubes by means of a 21 cu. ft. per minute blower. The air is exhausted through two 3-inch diameter circular openings over the tubes in the top cover. To maintain the shielding intact, these are covered with perforated aluminum.

A Barker and Williamson Model 850 band-switching pi-tank inductor is used in the output circuit. It is tuned by a vacuum variable capacitor operated through the counter dial (Groth TC-3) shown in the panel view.

Circuit Details

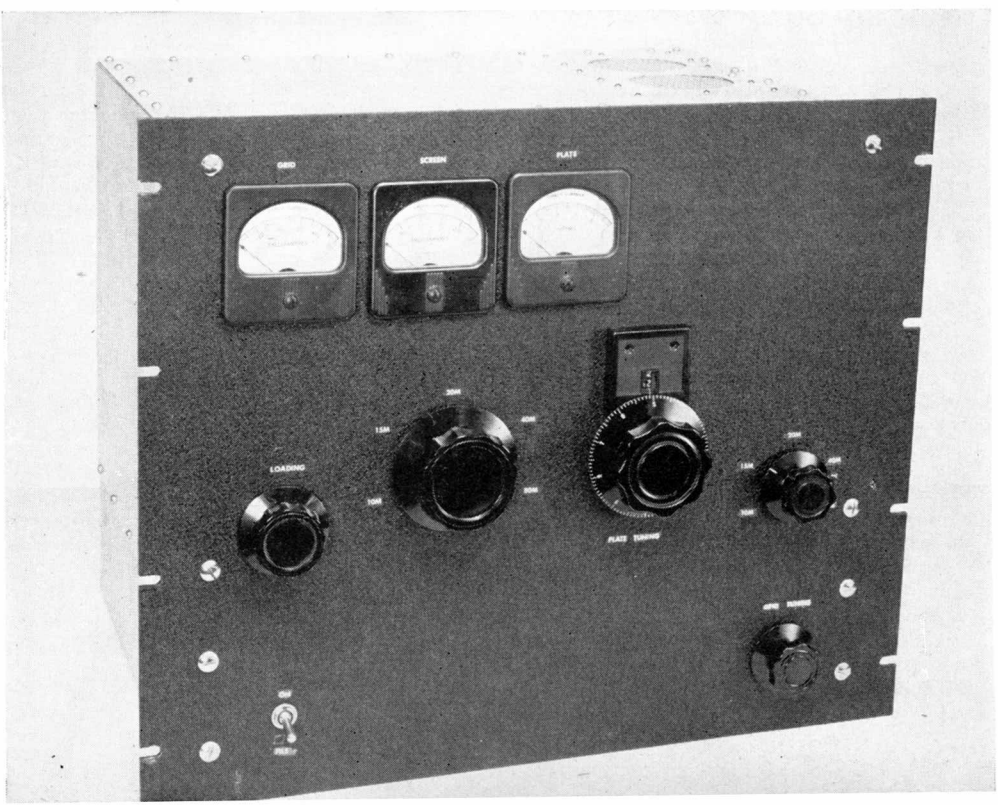
The circuit, Fig. 6-83, is electrically the more-or-less standard arrangement of a parallel-tuned grid circuit and a pi-network output circuit. The amplifier is neutralized by the capacitive bridge method. A filament transformer is included, but all other voltages come from external supplies.

The grid input circuit of the amplifier uses a slightly modified B&W turret assembly. The grid coils are tuned by a 75-$\mu\mu$f. variable. The 20-, 15-, and 10-meter coils each must have a few turns removed for proper grid tuning on these bands.

The circuit includes a 2000-ohm grid leak and has provisions for external bias, which should be used in combination with the leak. The by-pass capacitors on the screen leads all carry a rating of 1600 volts. This rating is necessary to avoid capacitor breakdowns when operating the amplifier screens at their rated voltages for AB_1 operation, and also with plate-modulated Class C operation where the 600-volt rating of the smaller ceramic capacitors would be exceeded on modulation peaks. All of the 0.001- and 0.003-μf. capacitors are the disk type, and aside from the screen by-passes are used mainly for filtering TV harmonics from the supply leads.

The by-pass capacitors in the high-voltage lead

Fig. 6-83—A 1-kw. final using a pair of 4-250-A's in parallel.



1-Kw. Amplifier

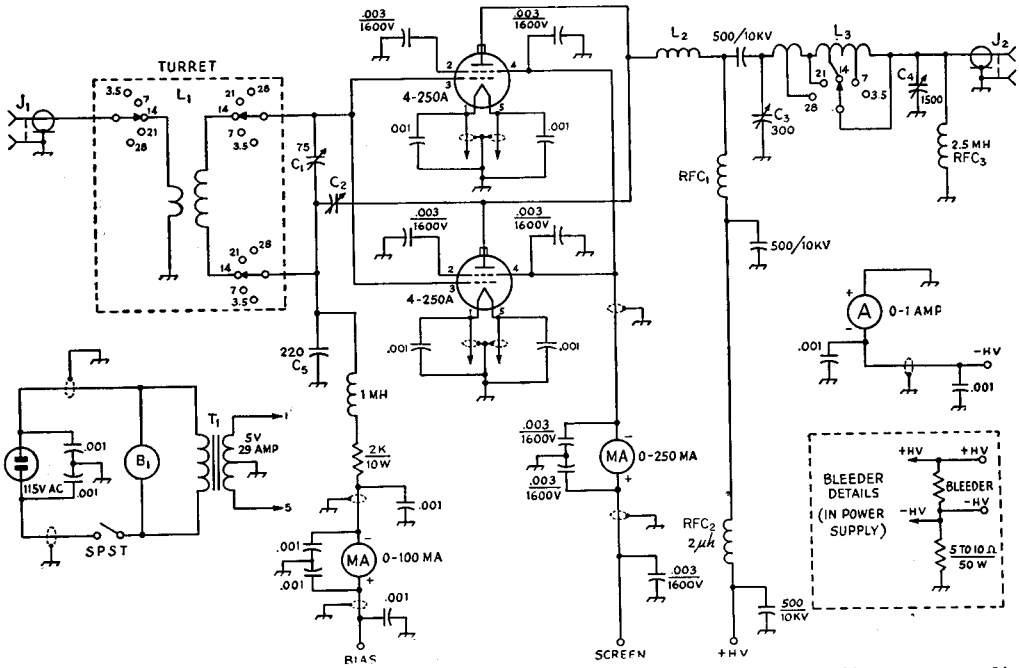


Fig. 6-84—Circuit diagram of the 4-250A amplifier.

B_1—Blower-motor assembly, 21 c.f.m. (Ripley model 8433).

C_1—75-$\mu\mu$f. variable, receiving spacing (Millen 19075).

C_2—7-$\mu\mu$f. neutralizing capacitor (Cardwell type ADN).

C_3—300-$\mu\mu$f. vacuum variable (Jennings type UCS).

C_4—1500-$\mu\mu$f. variable (Cardwell type 8013).

C_5—220-$\mu\mu$f. mica or NPO ceramic.

J_1, J_2—Coax receptacle, chassis mounting.

L_1—Turret assembly (B&W BTEL with 14-, 21-, and 28-Mc. coils modified by removing turns).
3.5 Mc.: 39 turns No. 22, 1¼ inches diam., ⅜ inches long, link 3 turns No. 18.
7 Mc.: 20 turns No. 20, 1¼ inches diam., 1W inches long, link 3 turns No. 18.
14 Mc.: 8 turns No. 18, 1¼ inches diam., ¾ inch long, link 2 turns No. 18.
21 Mc.: 4 turns No. 16, 1¼ inches diam., ½ inch long, link 1 turn No. 18.
28 Mc.: 2½ turns No. 16, 1¼ inches diam., ½ inch long, link 1 turn No. 18.

L_2—V.h.f. parasitic suppressor, 4 turns No. 12, ¼ inch dia., turns spaced wire diameter.

L_3—Pi-tank inductor (B&W Model 850). Inductances as follows: 3.5 Mc., 13.5 μh.; 7 Mc., 6.5 μh.; 14 Mc. 1.75 μ.; 21 Mc., 1 μh.; 28 Mc., 0.8 μh.

RFC_1—National type R175A r.f. choke.

RFC_2—2-μph. 500-ma. r.f. choke (National type R-60).

RFC_3—2.5-mh. r.f. choke.

T_1—Filament transformer, 5 volts, 29 amp. (Thordarson T-21FO7-A).

are the TV high-voltage ceramic type, as is also the blocking capacitor in the tank circuit. The loading capacitor, C_4, in the output circuit of the amplifier is a variable having enough range (1500 $\mu\mu$f. total capacitance) to give adequate loading on 80 through 10 meters when working into a 52- or 75-ohm resistive load.

Plate current is metered by a 0–1 ammeter shunted across a resistor in the negative high-voltage lead. As shown in Fig. 6-84, this resistor is incorporated in the power supply, not in the amplifier unit. A 50-watt rating represents an ample safety factor, since the power dissipated would not exceed a few watts should the ammeter open up.

Separate milliammeters are provided for the grid and screen circuits. The screen meter is quite essential since the screen current, and hence screen dissipation, is very sensitive to grid driving voltage and plate tuning.

Layout Details

Fig. 6-85 is a view looking into the amplifier with the top cover removed. The variable capacitor at the right is the output loading control, C_4. To the left of C_4 is the Model 850 inductor unit. Immediately to the rear (below, in the photograph) of the inductor is the output lead, connected to a coaxial receptacle mounted on the rear cover. The vacuum variable, C_3, is mounted between the inductor and the 4-250As. It is supported by an aluminum bracket 6 inches high and 4 inches wide. The neutralizing capacitor C_2 is between the 4-250As and the front panel.

The grid turret and tuning capacitor are mounted underneath the chassis to take advantage of the shielding afforded thereby. To fit under the chassis the turret is mounted with the switch shaft vertical, necessitating a right-angle drive to the panel control. The shaft approaches the panel at an angle, so a flexible coupling of the ball type (Millen 39001) is used between the shaft and panel bearing.

The meters are in a separate enclosure measuring 11 × 3 × 3-inches. It is mounted to the front of the box by countersunk flat-head screws. The top lips of the meter box are drilled to take sheet-metal screws when the lid is in place.

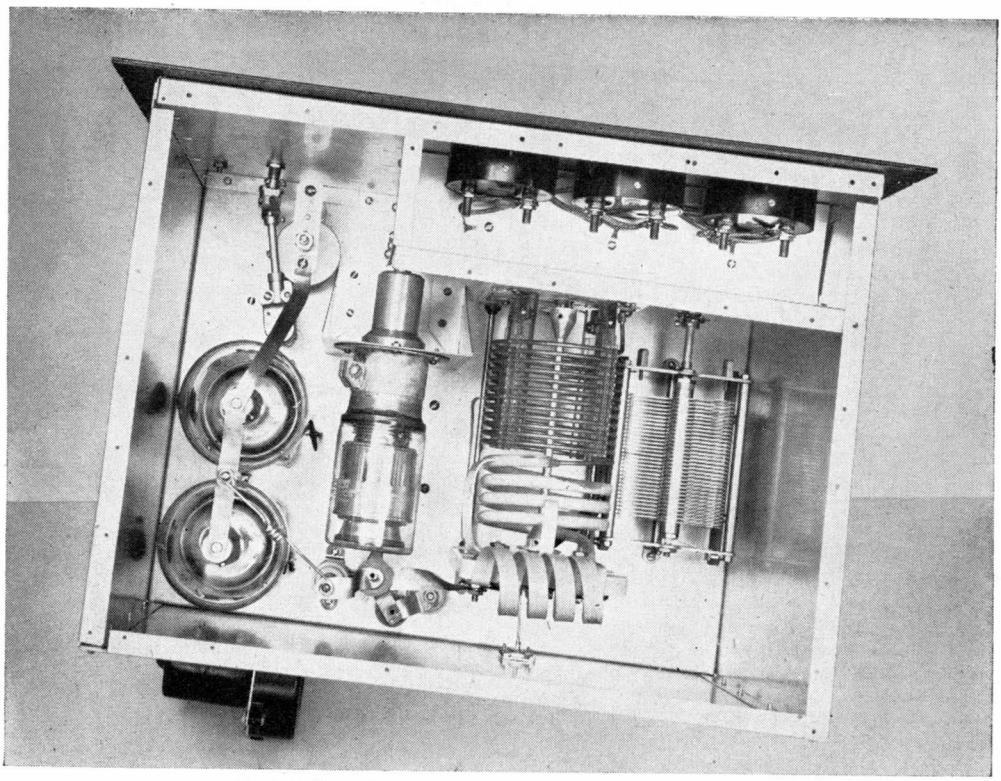


Fig 6-85 (above)

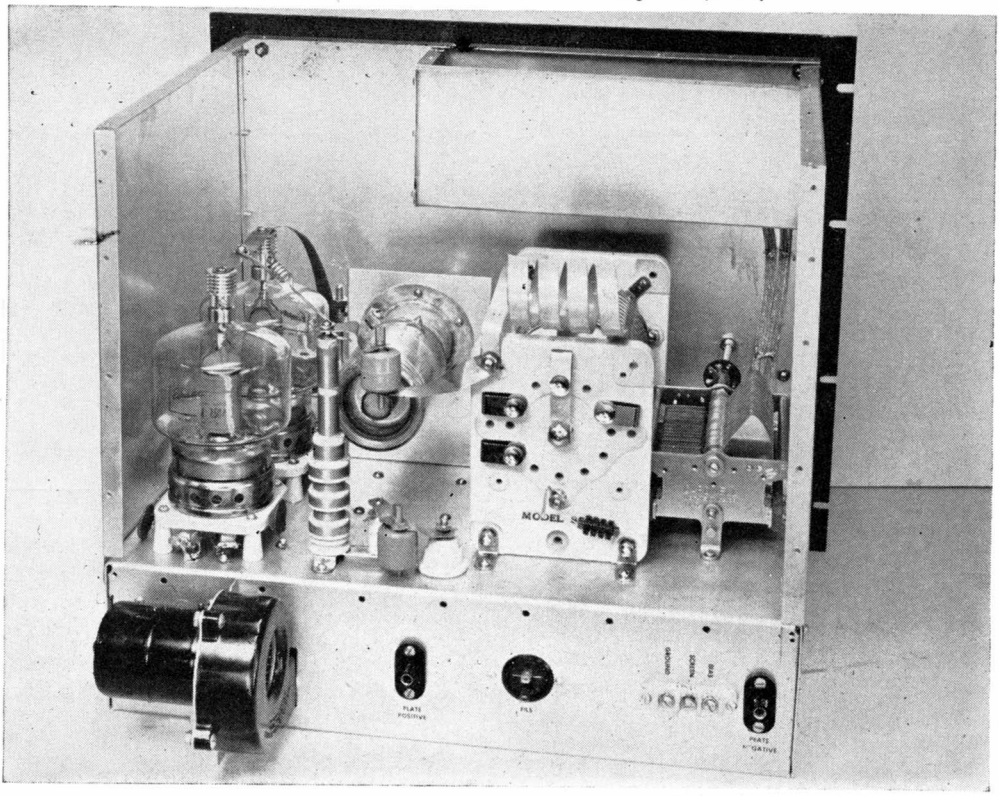


Fig. 6-86 (below)

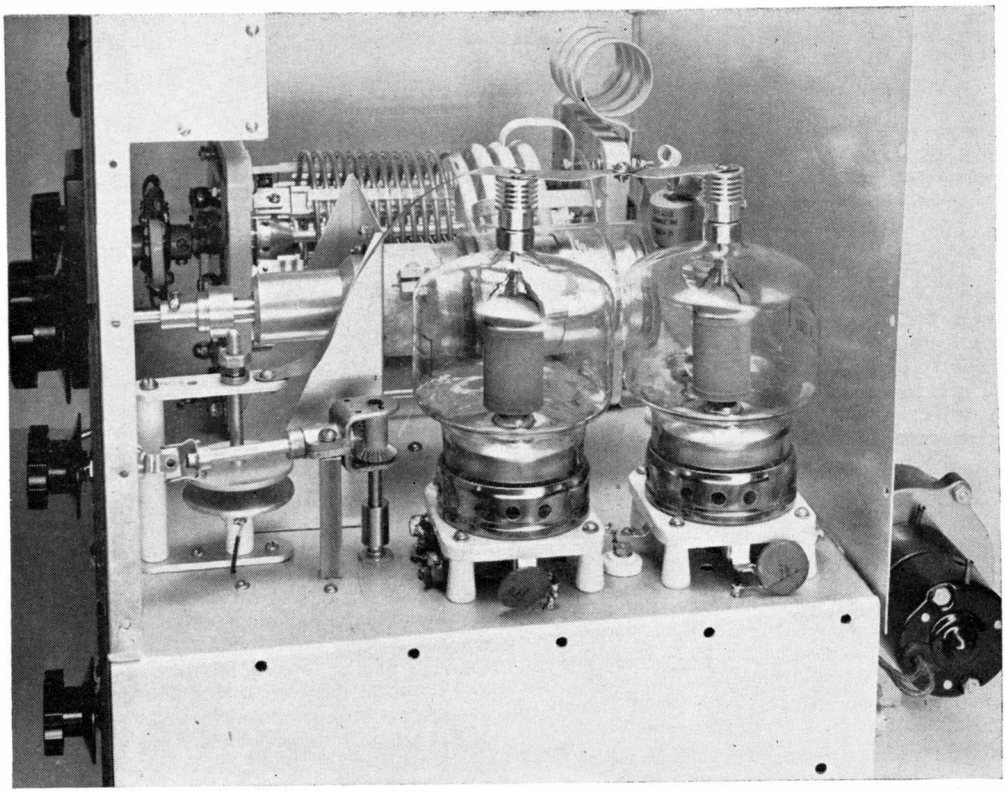


Fig. 6-87

Connections to the tube plates and neutralizing capacitor are made from flexible brass strip ½ inch wide. A piece of ¾-inch wide brass strip is used for the connection between the stator terminal of the vacuum variable and the tank inductor. The blocking capacitor is mounted on this strip.

Fig. 6-86 shows the amplifier with the top and back panels removed. The blower assembly is mounted on the rear chassis wall. To the right of the motor is the high-voltage terminal, the 115-volt connector, the grid and screen terminals, and the high-voltage negative connector. Leads from these last three terminals run below chassis in shielded wire and then up to the meter box. These leads are visible in front of the loading capacitor. Belden 8885 shielded wire is used for the leads. The inner conductor is bypassed to the shield braid at each end. The 2.5-mh. "safety" choke, RFC_3, shunting the output end of the pi network is mounted on the back of the tank coil between the output lead and chassis ground.

The isolantite feed-through insulator to the left of the inductor is used to bring the high voltage through the chassis. Adjacent to it is the bypass at the bottom of the plate choke, RFC_1.

Mounting details of the right-angle drive assembly for switching the grid circuit are clearly visible in Fig. 6-87. A ½-inch square rod 2¾ inches long is drilled and tapped at both ends to support the drive.

The sockets for the 4-250As are mounted on one-inch isolantite pillars. The screen and filament terminals are bypassed directly at the socket terminals. The grid terminals on the sockets face each other, and a small feedthrough is used to bring the grid lead up through the chassis.

Fig. 6-88 is a bottom view of the amplifier and Fig. 6-89 is a close-up view of the grid circuit. A short length of RF-58/U is used to connect J_1 on the rear chassis wall to the link terminals on the turret assembly. The high-voltage lead is filtered by the 500-$\mu\mu$f. ceramic bypass and RFC_2. These two components are visible on the inside of the rear wall above the blower assembly. Two-terminal tie-points are used for the a.c. connections to the filament transformer and blower motor. Shielded leads are used between the tie-points and the 115-volt connector.

Fig. 6-89 shows the grid-circuit wiring in a bit more detail, particularly the grid choke, grid resistor and C_5 clustered just above the tuning capacitor. The modifications to the 10- and 15-meter coils also are somewhat more easily seen in this photograph.

Adjustment and Operating Data

The amplifier should be neutralized with the plate and screen supply leads disconnected and the bandswitch set to 28 Mc. An indicating wave meter should be coupled to the tank circuit and drive applied to the amplifier. Resonate the grid

and plate tanks and adjust the neutralizing capacitor for minimum r.f. in the tank circuit as indicated by the wave meter. The same neutralizing adjustment should hold for all bands. Don't attempt to neutralize with the plate and screen supply leads connected — i.e., with a complete circuit for d.c. — because even with the power turned off this permits electrons to flow from the cathode to the plate and screen, and r.f. will be present that cannot be neutralized out.

The parasitic choke will, in general, resonate the plate lead in one of the low v.h.f. TV channels, and will tend to increase harmonic output in that channel. Measure the resonant frequency of the plate lead at L_2 with a grid-dip meter, and if it is in one of the channels received in your locality, either pull the turns apart, or squeeze them together to move the frequency to an unused channel. Any frequency from 70 to 100 Mc. should be satisfactory.

Power Supply

For 1 kw. input, a plate voltage of at least 2000 is required. Screen voltage is obtained preferably from a separate 400-volt supply. For Class C operation, an external bias supply regulated by a VR-150, plus a grid leak of 2000 ohms is recommended. With this combination, the grid current should be 25 ma. Screen current should be about 60 ma. with the amplifier fully loaded.

Some sort of r.f. output indicator, such as a crystal-rectifier voltmeter or r.f. ammeter in the feed line, should be used in tuning. It is preferable to do the preliminary tuning with the plate voltage applied to the tubes but with the screen voltage at zero. Zero screen voltage, provided the d.c. screen circuit is complete, will give enough output for tuning adjustments. C_2 and C_4 are adjusted to give maximum output, and the screen voltage is then increased until the amplifier is running at the desired input. C_3 is of course tuned for the plate-current dip so that the amplifier tank is kept tuned to resonance.

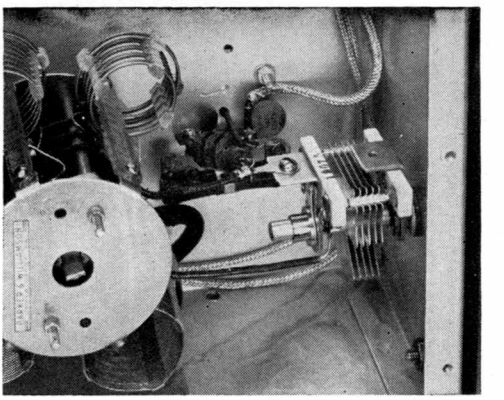


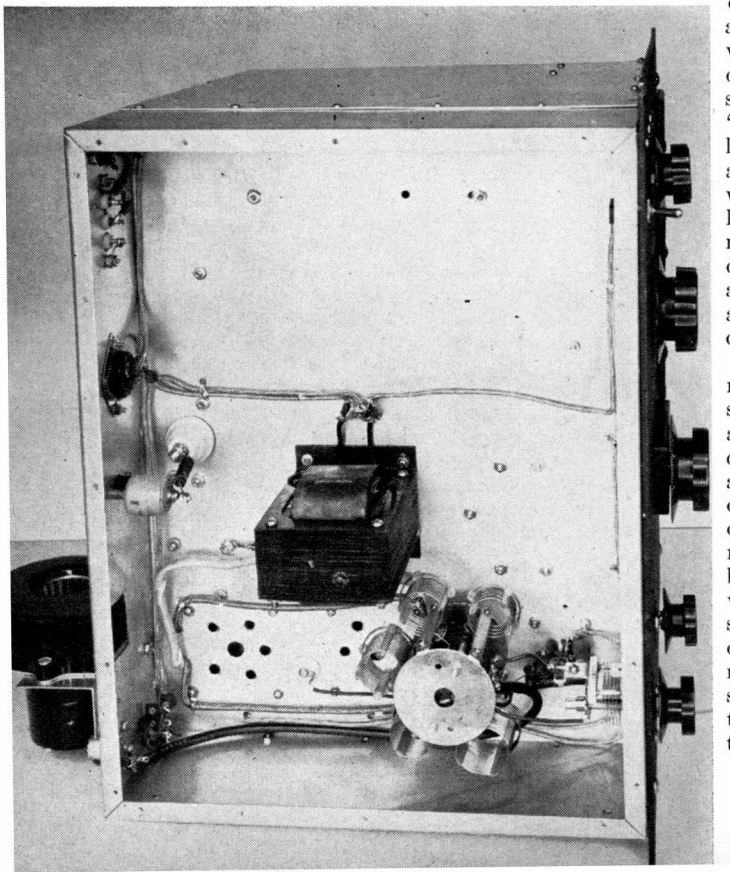
Fig. 6-89

The fixed values of inductance available in the B&W unit preclude the possibility of matching over a wide range of impedances. The circuit can handle an s.w.r. in the coax line of about 2 to 1, but with higher s.w.r. values it may not be possible to get the desired loading. Also, although the construction is such that the amplifier is "clean" insofar as direct radiation and leakage of harmonics in the TV bands are concerned, a good low-pass filter will be required in most installations. A low s.w.r. in the coax line is definitely a requirement if excessive build-up of currents or voltages in the filter is to be avoided. If the line cannot be matched at the antenna, an auxiliary antenna coupler will have to be used.

For plate modulation a choke coil may be connected in the d.c. screen lead so the screen voltage will follow the audio variations in plate voltage. The choke should have an inductance of about 10 henrys, and must be capable of carrying 125 ma. d.c. For Class AB_1 operation on single side band the circuit may be left intact, the only requirement being to supply the proper operating voltages from suitably well-regulated supplies. If the amplifier is to be operated in AB_2 on s.s.b. the grid-leak resistor should be shorted out; also, suitable loading should be applied to the grid tank to maintain good regulation of the r.f. driving voltage.

(From *QST*, June, 1956.)

Fig. 6-88



This amplifier operates at a plate input of approximately 500 watts, uses a pair of 811As in grounded-grid, and is complete with power supply on a 13 × 17 × 4-inch chassis. The rack panel is 10½ by 19 inches. Front-panel controls, arranged to give a balanced appearance, include the plate tuning capacitor and band switch in the center, filament and plate power switches with their pilot lights at the lower left, sensitivity control and forward-reflected power switch for the directional coupler at the lower right, variable loading capacitor and auxiliary loading-capacitor switch underneath the 0-1 milliammeter at the right, and the grid-cathode milliammeter with its switch at the upper left. The filter choke, 866As and plate transformer occupy the rear section of the chassis.

A Table-Top Half Kilowatt

Grounded-Grid Parallel 811As for S.S.B. or C.W.

An amplifier-cum-power supply on one chassis is a convenient package to have, especially when it fits in a receiver-size table-type cabinet and can be run at a half kilowatt input. Add constructional simplicity, a minimum of operating controls, and pleasing appearance and you have the article described here.

BY ERNEST A. COONS,* WIJLN/FOE

The amplifier shown here will run at about 500 watts input on c.w. — or p.e.p. input as an s.s.b. linear — on all bands from 80 through 10 meters. I wanted a simple amplifier that would be small and neat, and with which I could change bands quickly. The result is small enough to sit on the operating table right along with the rest of the station equipment; no need for big racks here!

Using a pair of 811As in parallel in the grounded-grid circuit, this rig is a good one to use following transmitters such as the Viking Ranger, DX-40, Globe Scout, and others of similar power class, for a worth-while increase in power output on c.w. As a linear amplifier following an s.s.b. exciter it requires no swamping not only because the 811A grids provide a fairly constant load in themselves, but also because the fed-through power with grounded-grid presents an additional constant load to the driver. The total driving power needed on any band is less than 20 watts.

An additional useful feature is a built-in directional coupler using a version of the "Mickey Match."[1] Besides its obvious application for checking the s.w.r. on the transmission line to the antenna or for help in tuning up a coax-coupled antenna coupler, it is practically indispensable as an indicator of relative power output in tuning the amplifier, for reasons which will be discussed later.

The Circuit

A number of tube types could be used in an amplifier of this power class, but I decided on the 811As because they do not need a bias supply and are not expensive. (Surplus 811s can be used if you don't want to buy new tubes; the ratings are not quite as high but they can be pushed a bit in intermittent service such as c.w. and s.s.b.)

The complete circuit is shown in Fig. 1. Don't expect to find anything startling — the whole thing was taken from parts of proven circuits here and there in the *Handbook* and put together to meet my needs. To save trouble and work, standard components were used throughout — the only special construction is the shielding and a few simple r.f. chokes. The tube filaments are driven directly from coax input from the driver; no tuning is used or is needed in this circuit. The filaments are kept above ground by the B & W type FC15 filament choke.

The plate tank is the familiar pi network, using a B & W type 851 tapped coil and band-switch assembly. This assembly has been modified slightly in two respects: First, the copper-strip 10-meter coil normally mounted at the top of the rear plate was taken off and moved so that it is supported between the tank assembly and the stator of the tank tuning capacitor as shown in

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[1] Bunce, "The 'Mickey Match'," *QST*, November, 1958. A modified version also is described in the chapter on measurements in the 1959 edition of *The Radio Amateur's Handbook*. The circuit used here combines the r.f. switching of the original "Mickey Match" with the fixed load resistor used in the *Handbook* arrangement. — *Editor.*

the top view. A short length of copper strip is bolted between the free end of the coil and the right-hand stator connection of the tuning capacitor, to support the free end. This change was made in order to avoid the long lead that would have had to be run from the capacitor to the regular input terminal on the tank assembly, since this terminal is at the right-hand side of the assembly as viewed from the top. The turns of the 10-meter coil were also squeezed together a bit to increase the inductance, because it was found that a rather large amount of capacitance had to be used to tune the circuit to the band with the coil at its original length. The length is now 1⅝ inches between mounting holes.

The second modification was the addition of a

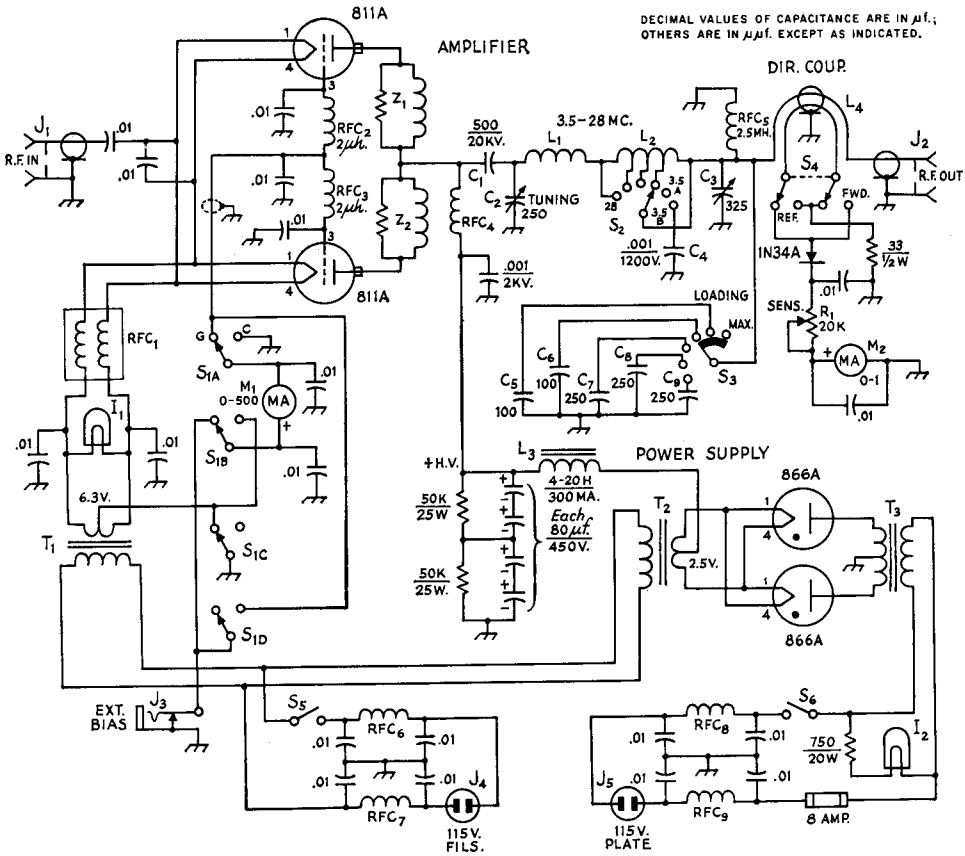


Fig. 1—Circuit diagram of the parallel-811A grounded-grid amplifier. Unless otherwise specified, fixed capacitors are disk ceramic, 600-volt rating.

C_1—500 μμf., 20,000 volts (TV "doorknob" type).

C_2—250-μμf. variable, 2000 volts (Johnson 250E20).

C_3—325-μμf. variable, receiving type (Hammarlund MC-325-M).

C_4–C_9, inc.—1200-volt mica, case style CM-45.

I_1, I_2—6.3-volt dial lamp, 150-ma. (No. 47).

J_1, J_2—Coax connector, chassis mounting.

J_3—Closed-circuit phone jack.

J_4, J_5—115-volt male connector, chassis mounting (Amphenol 61-M1).

L_1, L_2, S_2—5-band pi-network coil-switch assembly; see text (B & W 851).

L_3—Swinging choke, 4-20 henrys, 300 ma. (UTC S-34).

L_4—Section of coax line with extra conductor inserted; see Footnote 1 for construction references.

M_1, M_2—Milliammeter, 3½-inch plastic case (Triplett 327-PL).

R_1—20,000-ohm composition control, linear taper.

RFC_1—Filament-choke assembly, to carry 8 amp. (B & W FC15).

RFC_2, RFC_3—2 μh. (National R-60).

RFC_4—90 μh.; 4⅜-inch winding of No. 26, 40 t.p.i., on ¾-inch ceramic form (B & W 800).

RFC_5—2.5 mh., any type.

RFC_6–RFC_9, incl.—18 turns No. 14 enam., close-wound, ½-inch diam., self-supporting.

S_1—4-pole 2-position rotary, nonshorting (Mallory 3242J or Centralab 1450).

S_2—Part of tank assembly; see L_1L_2.

S_3—Miniature ceramic rotary, 1 section, 1 pole, 6 positions used, progressive shorting (Centralab 2042).

S_4—Miniature ceramic rotary, 1 section, 2 poles, 2 positions used, nonshorting (Centralab 2003).

S_5, S_6—S.p.s.t. toggle.

T_1—Filament transformer, 6.3 volts, 8 amp. min. (UTC S-61).

T_2—Filament transformer, 2.5 volts, 10 amp. (UTC S-57).

T_3—Plate transformer, 3000 volts center-tapped, 300 ma. d.c. (UTC S-47).

Z_1, Z_2—Parasitic suppressor, 100-ohm 2-watt carbon resistor assembled inside 2½-turn coil of No. 16 tinned, ½-inch diameter, ¾-inch long.

pair of switch contacts on the rear switch plate of the tank assembly. There is an extra position on this plate with holes already provided for contacts, and it seemed like a good idea to use a set of contacts here to switch in additional output loading capacitance on 80 meters, where a large output capacitance is needed. The variable loading capacitor, C_3, and the five fixed mica capacitors, C_5 to C_9 inclusive, give continuous variation of capacitance up to 1275 $\mu\mu$f. on all bands, including the regular band-switch position for the 80-meter band. However, if the switch is turned to the extra position an additional 1000-$\mu\mu$f. mica capacitor is connected in parallel, so that continuous variation of capacitance to over 2200 $\mu\mu$f. is possible on 80. This takes care of cases where the load resistance happens to be unusually low or reactive.[2]

A 500-ma. d.c. meter is used for reading either total cathode current or grid current alone. The cathode current is read in preference to plate current because of safety considerations. Putting the meter in the hot d.c. plate lead leaves nothing but a little plastic insulation between the high voltage and the meter adjusting screw. Although the meter could have been connected in the negative plate supply lead since the power supply is self-contained, I prefer to have the negative firmly grounded to the chassis. It is a bit of a nuisance to have to subtract the grid current from the cathode current in order to find the plate current, but it isn't serious. The d.c. grid circuit has a jack, J_3, for introducing external bias either for blocked-grid keying or for cutting off the plate current during receiving, and a four-pole switch, S_1, is therefore needed for handling the meter switching while keeping all circuits functioning normally.

The power supply uses 866As with a plate transformer giving 1500 volts each side of the center tap, and working into a single-section choke-input filter. The filter capacitor consists of four 80-μf. electrolytics connected in series to handle the voltage, giving an effective filter capacitance of 20 μf. This supply is running well below its capabilities in the intermittent type of operation represented by c.w. and s.s.b., and the amplifier is somewhat "over-powered" in this respect. A lighter plate transformer can be used since the average current in regular operation is only about half the maximum tube rating of 350 ma. for the pair. However, a heavier supply was used here because plate modulation may be tried some day. This might make it necessary to use a tank capacitor with larger plate spacing (3000-volt rating instead of 2000 volts, which is plenty adequate for c.w. and s.s.b.) but there is room enough to install a capacitor about two inches longer if it is needed.

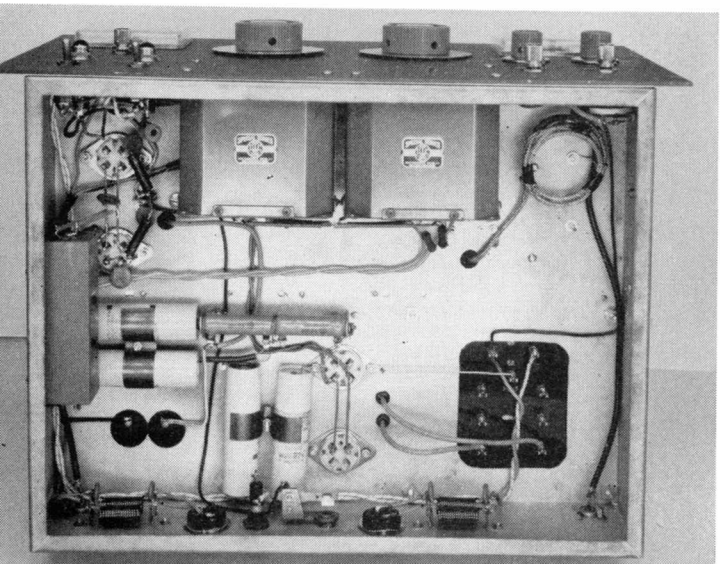
The a.c. inputs to both filaments and plates have TVI filters installed right at the a.c. connectors. The chokes in these filters, RFC_6 to RFC_9 inclusive, are homemade by winding 18 turns of No. 14 enameled wire close-wound on a half-inch dowel or drill.

Construction

The ordinary principles of good construction as given in the handbooks were followed in layout and assembly. The only space available for the filament transformers was below chassis, so these were mounted on the front wall of the chassis as shown in the bottom view. There is plenty of room for all other power-supply parts below chassis, and the photographs make any further comment on this section unnecessary.

The r.f. layout shown in the top view is almost an exact copy of the circuit layout as given in Fig. 1. The plate blocking capacitor, C_1, is mounted on a small right-angle bracket fastened to the left-hand stator connection of the tank capacitor, C_2. The tube plates are connected to C_1 through individual parasitic-suppressor assemblies, Z_1 and Z_2. The hot end of the plate choke, RFC_4, also connects to this same point. The tank capacitor is mounted on ¾-inch ceramic pillars to bring its shaft to the same height as the switch shaft on the tank-coil assembly. The capacitor is grounded by connecting the bottom of its frame through a half-inch wide strip of

[2] These contacts can be obtained directly from the manufacturer of the tank assembly. To secure a set of contacts with mounting hardware, send one dollar to Barker & Williamson, Beaver Dam and Canal, Bristol, Penna., specifying the type of tank assembly for which they are wanted. The contacts are not catalog items and are not available through dealers.—*Editor.*



In this below-chassis view, the two filament transformers are at the top, mounted on the chassis wall. The 811A sockets are at the upper left. The rectangular box on the left-hand wall contains the FC15 filament-choke assembly. The "Mickey Match" directional coupler is at the upper right. Filter capacitors and the bleeder resistors are in the lower section. A.c. inlets, fuse holder, bias jack, and the 115-volt line TVI filters are on the bottom chassis wall.

aluminum to essentially the same point at which the plate-choke bypass capacitor, a 0.001-μf. 2000-volt disk, is grounded. The ground end of the aluminum strip actually is under the bottom of the plate choke, and the ground lug for the bypass capacitor is just to the left. This strip, plus short leads in the circuit from the tube plates through the tank capacitor to ground, keeps the resonant frequency of the loop thus formed well up in the v.h.f. region; this is important because it permits using low-inductance parasitic chokes in shunt with the suppressor resistors, and thus tends to keep the r.f. plate current at the regular operating frequencies out of the resistors. With other tank grounding arrangements originally tried, larger parasitic chokes had to be used and it was impossible to prevent the resistors from burning up when operating on 10, 15 and even 20 meters. Now they do not overheat on any frequency, and v.h.f. parasitics are nonexistent — although without the suppressors the parasitics are only too much in evidence.

The output loading capacitors, C_3 through C_9, are mounted toward the rear so the leads from the tank coil can be kept as short as possible. A length of copper strip is used between the coil and the stator of C_3; originally this lead was No. 14 wire but on 10 meters the tank current was enough to heat it to the point of discoloration. The ground lead from the fixed units, made to the rear bearing connection of C_3, is also copper strip. C_3 and S_3 are operated through extension shafts, using Millen flexible couplings to simplify the alignment problem.

Underneath the chassis, each 811A grid is bypassed directly to the socket-mounting screw nearest the plate choke (right-hand side of the socket in the bottom view). The d.c. leads have small chokes, RFC_2 and RFC_3, with additional bypasses for good r.f. filtering, particularly at v.h.f. since grid rectification generates harmonics in the TV bands. The filament choke, RFC_1, is mounted so that the filament side is close to the filament terminals on the tube sockets; the other end is bypassed directly to the chassis.

The shielding around the amplifier consists of two pieces of sheet aluminum and a perforated aluminum ("do-it-yourself" type) cover having the shape of an inverted U. The top view shows how the rear wall is made. Its edges are bent to provide flanges for fastening the cover with sheet-metal screws, and there is a similar flange projecting to the rear at the bottom for fastening the wall to the chassis. The front piece extends the full height of the panel and is identically drilled and cut out for meters and controls. It has flanges at the top and extending down the sides from the top to the chassis. The cover itself extends down over the sides of the chassis for about one inch. Numerous screws are used for fastening the cover, to prevent leakage of harmonics.

The shields over the meters are made as described in the caption for the inside top view. Meter leads are bypassed to the shield boxes where they emerge.

The *Handbook* should be consulted for methods of checking and adjustment of the directional coupler.

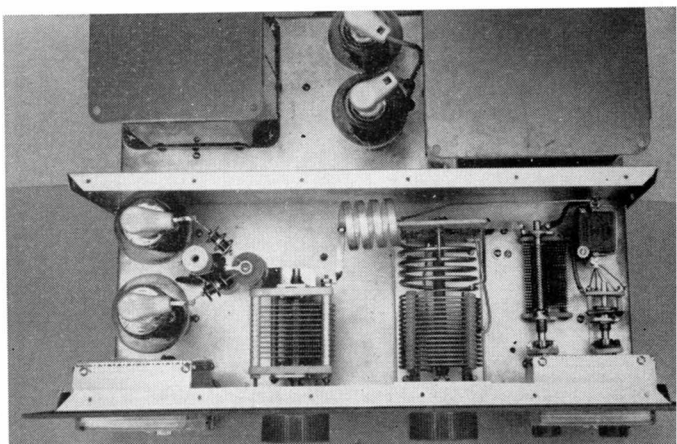
Operating Conditions and Tuning

The voltage delivered by the power supply is approximately 1500 volts with no drive and with the tubes taking only the no-bias static plate current, which is about 60 ma. At the full load of 350 ma. the voltage is slightly under 1400. Optimum operating conditions for 1400 volts at 350 ma. peak-envelope power input as an s.s.b. linear call for a peak-envelope grid current of 60 ma. The peak-envelope tube power output is close to 350 watts under these conditions. The same operating conditions are also about optimum for c.w.

The behavior of the cathode current when tuning a grounded-grid triode amplifier is extremely confusing, and the meter is principally useful as a check on operating conditions rather than as a tuning indicator. The best indicator of proper tuning of the plate tank capacitor is the forward-power reading of the directional coupler. For any trial setting of the loading controls and driving power, *always* set the plate tank capacitor control at the point which results in a maximum reading on the power-output indicator. The power indications are only relative, of course, and the sensitivity control should be set to give a reading in the upper half of the scale.

The objective in adjusting loading and drive is to arrive at maximum power output simultaneously with a plate current of 350 ma. and a grid current of 60 ma. — that is, a total cathode current of 410 ma. when the grid current reading is 60 ma. The loading is critical. If the amplifier is not loaded heavily enough the grid current will be too high and the right value of total cathode current either will not be reached or, if reached, the amplifier will be operating in the

(*Continued on page 156*)



The r.f. section with the shield cover removed. Components here are readily identifiable by reference to the circuit diagram. The meters are enclosed in rectangular boxes made from thin aluminum sheet, formed to be fastened by the meter mounting screws. The back covers on these boxes are made from perforated aluminum, folded over at the edges and held on the boxes by sheet-metal screws. The switch for shifting the 0-500 milliammeter (left) from grid to cathode is concealed by the box which encloses the meter.

Table-Top Half Kilowatt

(*Continued from page 27*)

"flattening" region as an s.s.b. linear. (It can be operated this way on c.w., however, since linearity is unimportant here.) If the loading is too heavy, the grid current will be low when the cathode current reaches the proper value, but the efficiency will be low and the tubes will overheat.

Getting the knack of it takes a little practice, but when the job is done right the tubes will run cool on all bands in regular operation. Running key-down over a period of time may show just a trace of dark red color on the plates since the input and dissipation are somewhat over ratings under these operating conditions, although perfectly satisfactory with ordinary keying or s.s.b. voice.

(*Continued on page 158*)

That's about it. Once you get it built and learn to operate it, you're in the high-power class — with a table-top job that takes up no more room than a good communications receiver. Nothing under the table, either. QST

How To Run Your Linear

What It Can Do and What It Shouldn't Do

BY GEORGE GRAMMER,* W1DF

Although amateurs always have operated and, by the nature of the service, always will operate in an environment of interference, much of the interference is avoidable. One such type is the spurious radiation that falls outside the necessary communication band. This article takes up one special case, the linear amplifier, and the spurious radiation that results from its mistreatment. Other aspects of the spurious-radiation problem will be treated in subsequent articles.

NO MODE of communication used by amateurs is free from a tendency to occupy more bandwidth than is actually needed. This is merely a way of saying that the devices we use are something short of perfect. Nor is it realistic to expect that perfection will ever be reached. In some degree, spurious radiations — those outside the frequency band essential to the intended communication — always will be with us.

Pessimistic? Only on the surface. The fact is acknowledged simply to emphasize a more pertinent one: The present state of the art offers the technical means for generating signals that are *acceptably* free from spurious radiation. Moreover, these means are commonly incorporated in equipment.

For example, the application of well-known principles can develop a single-sideband signal in which the output in the unwanted sideband is 30 db. below the peak-envelope output in the desired sideband. That is, a signal peak of a kilowatt in the desired sideband will generate no more than one-watt peak in the "undesired." While not wholly negligible, this is hardly the sort of power level destined to make a big noise in the world. [1]

The state of the art gives a measure of the spurious radiation, and thus interference to others, that is *technically* unavoidable. But most of the spurious that causes interference troubles isn't of this nature. It is strictly in the *unnecessary* classification. The deficiencies which cause it are not in the equipment but in the operator. A major one is simply lack of knowledge of how things are supposed to work. This can be overcome. A less pleasant one is lack of good citizenship — deliberate misuse of the equipment for some hoped-for advantage. Whether this can be overcome is dependent on moral pressure from those who believe in letting others have the same chance for good contacts that they want for themselves.

Most hams would stay within decent bounds if they knew how. Their equipment has the capability of good performance, so it's mostly a question of appreciating that it does have limitations. These vary with the kind of emission — c.w., s.s.b., a.m., and so on. As they can't all be covered at one sitting, let's look at s.s.b. first.

S.S.B. Spurious

A single-sideband transmitter has four principal sections:

1) A balanced modulator, in which the carrier is suppressed and the two sidebands are generated. This usually operates at a fixed frequency.

2) A means for suppressing one of the sidebands.

3) Circuits for shifting the remaining sideband to the desired amateur band.

4) A linear amplifier for building up the output power.

Spurious frequencies can be generated in any

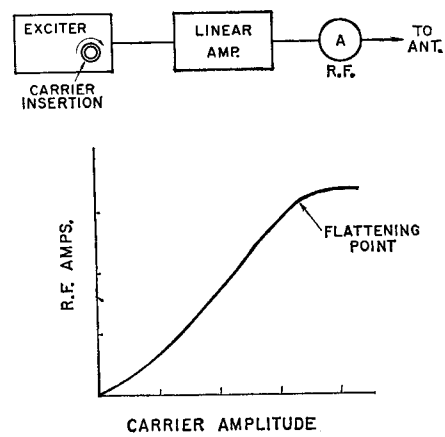


Fig. 1—Simple test setup for determining the proper operating limits of a linear amplifier. The curve below is typical of what would be obtained if the amplitude of the signal at the grid and the amplitude of the linear's output could be measured accurately. However, it isn't necessary to make such measurements to find the flattening point.

* Technical Editor, *QST*.

[1] Except, perhaps, within a few hundred yards of the transmitter. But here the receiver becomes suspect, because it is quite capable of manufacturing its own spurious from the exceptionally strong "desired" that it is trying to eliminate. Under such circumstances the interference probably would be there even if the transmitter were perfect.

of these four sections, but in practice the contributions of the first three usually are much less bothersome than that of the fourth.[2] These three sections operate at rather low signal levels, in most designs. This is a favorable condition for minimizing the distortion that is the root cause of spurious.

We'll therefore lay aside the first three at this point, not because they will not later require attention, but because doing something about No. 4, the linear amplifier, is much more urgent. Possibly not doing so much about the amplifier itself as about its operator, because it isn't use but *abuse* that accounts for most of the unnecessary QRM.

The Envelope Peak

The evidence strongly suggests that the main reason for the abuse of linear amplifiers is that the operator doesn't understand the difference between peak and average power. You can't just say "power is power" and let it go at that. In s.s.b., the only meaningful way of rating a linear amplifier is in terms of the *peak-envelope* power it can handle without exceeding some specified degree of spurious output.

The peak-envelope power doesn't show on a meter, and therein lies the difficulty. Only an oscilloscope pattern gives a visible measure of it; even then you have to know what to look for. In voice transmission, peaks come along irregularly and fleetingly; they don't last long enough to let a meter show them.

If your transmitter has provision for inserting an adjustable amount of carrier up to the c.w. level, you can get the "feel" of it by performing a simple experiment. Connect an r.f. indicator to the output end of the transmitter (Fig. 1). An r.f. ammeter is good because its calibration will be reasonably accurate, but the more common rectifier-type r.f. voltmeter will do. (Many such voltmeters tend to give square-law rather than linear response, but this does not affect the end result.) Start with the carrier balanced out, and then gradually increase the inserted-carrier amplitude. Watch the output meter as you do this.

If the amplitude of the carrier voltage at the linear's grid and the amplitude of the output current in the transmission line can be measured, both with good accuracy, the relationship between the two will be something like the graph in Fig. 1. Doubling the driving voltage will double the output current (or voltage) — that is, the plot of the input and output amplitudes will be essentially a straight line — *up to a point.* After a while you will find that the output stops increasing as you continue to increase the carrier level. The point where the plot begins to depart from straightness is the flattening point. When the amplifier is driven by an s.s.b. signal instead of with unmodulated carrier, the proper peak-envelope level is just below this. As you go farther into the flattening region with an s.s.b. signal the spurious output rapidly increases. (On your carrier insertion test nothing of the sort happens, because at least *two* frequency components have to be present before spurious is generated. With voice, there are many such frequency components.)

The flattening point can usually be observed quite plainly in this test even if the r.f. indicator is not very linear. Above some setting of the carrier control there is simply no change in the linear's output amplitude. When you find this region, back off on the carrier insertion until the output starts to drop. This is the proper peak-envelope level in most linears, particularly in the Class AB_1 type where the flattening point is usually unmistakable.

[2] This is not so in every case, of course. It can be assumed that the statement is accurate in the case of factory-built equipment that is in good alignment. It is also accurate for homemade transmitters that have been properly designed and adjusted.

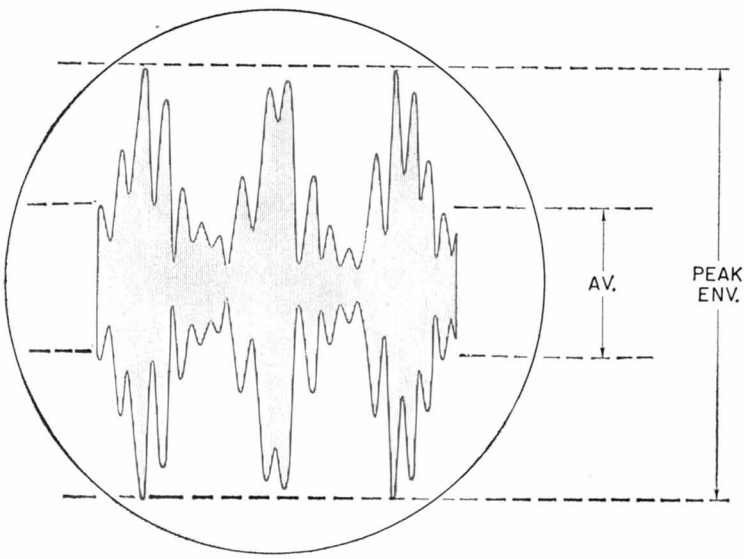


Fig. 2—An s.s.b. signal will have this general appearance on an oscilloscope when the amplifier is operating within its capabilities.

Average Amplitude

Having found the flattening point, leave the carrier adjustment there and connect in a key, preferably a bug. Make a series of fast dots, trying for ideal spacing — space and dot both the same length. Watch the output indicator. If it's an r.f. ammeter, it should read just about half what it did at the peak-envelope level. If it's an r.f. voltmeter with poor linearity, the reading may be considerably less than half. The meter is now reading *average*, not peak-envelope, amplitude, and if your dot/space timing is perfect you're seeing the average output amplitude with a 1 to 2 average-to-peak ratio. Remember that *fast* dots have to be used so the meter doesn't have time to get up toward the peak level.

With voice modulation, the ratio of average to peak almost never is any higher than this, and generally is considerably less. If you regularly use an r.f. indicator in your s.s.b. transmissions and it has been reading higher than what you've just seen, better turn down the audio gain control until you don't go over this dot/space reading at any time. Even such a reading may be too high for *your* voice.

The r.f. output amplitude, which is what was looked at in this test, is zero with a linear when there is no r.f. at its grid. This won't be true of the amplifier's plate current, usually, because there is nearly always a certain amount of "resting" current. However, the linear's plate current can easily be correlated with r.f. readings. Simply observe the plate current that corresponds to the two conditions — peak-envelope and average — and especially the average plate current with the fast dots. This is the value of plate current that you should never exceed when you talk.

The test as described is at best a rough-and-ready way to find out the greatest permissible meter swing. Its principal value is to bring home the difference between peak-envelope and average when the signal amplitude is varying, as it does in a modulated signal. But even this optimistic reading may come as a somewhat unpleasant surprise in view of what you've been doing customarily. The proper average reading may be considerably less, for your voice. With an oscilloscope you can not only establish the proper levels but also can keep tabs on your transmissions continuously.

Oscilloscope Pattern

Whether or not you have a scope, the type of picture you would see on its face will further illustrate the difference between peak-envelope and average power. Fig. 2 shows what an s.s.b. signal might look like when displayed on a scope. The scope shows the amplitude of the voltage variations in the signal, against time. The signal in this picture is assumed to be properly generated and amplified, and would produce no spurious output frequencies. Notice that even the highest peaks are clean — the tips are rounded somewhat like the tips of a sine wave are rounded. The tips may be a little hard to see in an actual display using a 60-cycle sweep, because only the lower voice frequencies would be wide enough to be distinguished in the scope picture; the higher-frequency components would tend to look more like straight vertical lines. However, they can be seen if the sweep is expanded enough, even if this means that a large part of the picture is off both sides of the screen. You only need to see a small part to appreciate what's going on.

The drawing indicates the peak amplitude of this envelope. It also shows the *average* amplitude of this particular waveform (determined graphically in this case). Here the ratio of peak to average is about 3 to 1, so if the peak-envelope amplitude was represented by an r.f. current of 2 amperes the average meter reading would be ⅔, or 0.67 amp.

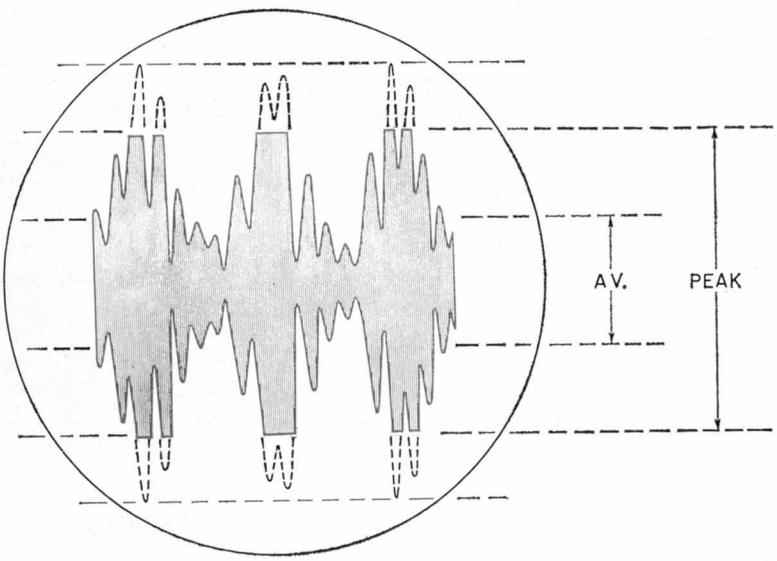


Fig. 3—The signal of Fig. 2 with peaks clipped, caused by driving the amplifier into the flattening region.

Now imagine this same waveform applied to the grid of a linear amplifier which is being driven into the flattening region. The amplifier clips off the peaks as shown in Fig. 3, where the height marked "Peak" represents the maximum possible output amplitude — the peak-envelope amplitude for that amplifier. There are several distinguishing features in this picture. One is that the peaks are no longer nicely rounded but are clipped off flat. Furthermore, the signal is at the peak level a lot of the time — far more than in Fig. 2, where only occasional peaks got up to the highest level. This means that the ratio of peak to average is lower — or, relative to the peak level, the average meter reading is higher. The peak-to-average ratio here has dropped to 2.4 to 1, so if the meter reads 2 amp. at the real peak-envelope level it will read 2/2.4, or 0.85, on a flattened signal such as this. More satisfying to the eye than the properly-amplified signal of Fig. 2, no doubt, since the ammeter's pointer swings almost twice as far.[3] But this flattened signal is putting a lot of its power into regions that aren't of any benefit to a receiver that is tuned to it. At this stage a lot of operators who might not otherwise know it are aware that you're on the air. But they are not *pleased* to know it.

With continuous scope monitoring you can easily determine whether your output is within proper bounds, once the peak-envelope level has been found. To find it, start talking with the audio at a low level and gradually increase the gain until the tips of the highest peaks just begin to be clipped. Then keep *below* this level with your audio. A few checks will show how far up the plate meter or r.f. meter should kick when you're just reaching the right peaks. You may find it easier to watch a meter than the scope face while transmitting.

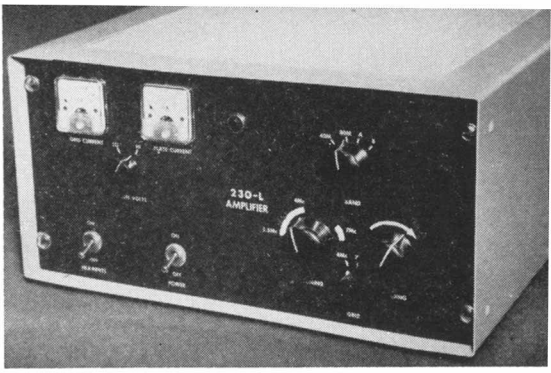
Keeping the output clean will take a good deal of self control. But it pays off: Not only will others no longer have reason to cuss your operating tactics, but your signal will sound better. You'll be a decent citizen.

[3] There are far worse cases than this in practice. The clipping shown in Fig. 3 is really moderate, compared with what frequently goes on.

Amplitude vs. *Power*

This discussion has been in terms of amplitude — current or voltage — because that is what meters and scopes show. Power, which is proportional to the square of the amplitude, is what is talked about most. In the fast-dot experiment, the average amplitude was one-half the peak amplitude, so the average power output was one-fourth the peak power. In Fig. 2, where the amplitude ratio is 1 to 3, the average output power is one-ninth or about 11 per cent the peak power. Going into the flattening region of the linear raises this to nearly 18 per cent of the peak power, in the example in Fig. 3, but the increase is accompanied by most undesirable results.

If you've attempted to correlate the plate-meter readings of your linear with the average r.f. output amplitude of a *properly* amplified signal, it should be clear by now that d.c. input has only a vague relationship to either peak-envelope amplitude or power. The only justification for rating a linear amplifier in d.c. input is that measuring input is the traditional way of setting a power figure that can be used for the purposes of government regulation. What the amplifier actually can handle is determined by its *peak-envelope* rating. If you're shopping, it pays to concentrate on the p.e.p. rating, and find out what that rating is based on — what percentage of spurious, and how it is calculated and measured. With the equipment you now have, forget about d.c. input except as a plate-meter reading that you've established as the *right* average for your voice when a voice peak is just below the flattening point. Unless, of course, the figure runs over a kilowatt! But that isn't likely, with any of the current transmitters on the market, or with high-power linear-amplifier designs that you've seen in QST—



The rotary switch between the two meters is for changing screen voltage. The toggles below control filament and plate power. To the right are the plate tank-tuning and loading controls, with the plate band switch above, and the grid switch below.

The homemade 7 × 14½ × 14½-inch wrap-around cabinet [1] is made of steel with similar cutouts in both top and bottom covered with expanded metal. Both front and back of the cabinet are open. The sides of the front are fitted with sections of angle stock against which the panel is fastened.

The RCC 230-L Amplifier

807s in a 230-Watt Linear for 80 and 40

BY J. L. COPELAND,* W5SQT

By heavily loading the grid circuit of this amplifier, the author achieves both the stability and broad-band input characteristics of a grounded-grid amplifier, but with a much lower driving-power requirement.

THE cost of an amplifier (in which the power supply is an important factor) runs approximately in proportion to the power level. In cases where economy is essential, it is well to remember that, other things being equal, the signal from a 250-watt transmitter will be down only one S point (6 db.) from the signal level of an amplifier operating at the maximum legal input of 1 kw. While the single S point may sometimes spell the difference between copy and no copy when working DX at low signal levels, it may serve merely to cause the receiving operator to turn his gain control down a bit in rag-chew operating over moderate distances where the average signal level is ordinarily relatively high. At the same time, the kilowatt job will cost about four times as much and will be approximately four times as large and heavy. With s.s.b. and c.w. rag-chew operating in mind, and minimum cost being essential, these considerations led to the 250-watt two-band unit shown in the photographs. The 80- and 40-meter bands were chosen as most appropriate for the purpose.

Within the last few years, the grounded-grid mode of operation has become popular because an amplifier of this type is simple to build and stabilize, and also because commercial s.s.b. transmitters in the 50- to 100-watt range required to drive the grounded-grid brutes have become widely distributed. Possibly for this reason, not as many articles on high-gain tetrode and pentode linears have appeared in the amateur journals. Although the amplifier described here is of the grounded cathode-type, it is also simple to build, is extremely stable, and has no tuning controls for the input circuit. It uses cheap tubes and can be driven to 230 watts input in Class AB_1 mode of operation. It uses two 807W beam power tubes (but 1625s and regular 807s can be used equally well) with 1100 volts on the plate and 408 volts on the screens. L networks are used in the grid circuit, and 2½ watts will drive the amplifier to 230 watts or more. The input presents a constant load of 50 ohms to the exciter. This amplifier was designed as a companion unit to an s.s.b. exciter delivering from 10 watts p.e.p. output down to one watt or less. The circuit of the amplifier is shown in Fig. 1.

Circuit

The grid circuit consists of an L network for each of the two bands. This network is designed to look like 50 ohms from the exciter input side when the grid side is loaded with a resistance of 500 ohms. These circuits have a Q of 3.[2] The fixed-tuned networks are switched into the grid of the amplifier by a band switch. Once the value of L is set for the band in use, no further adjustment is required. The networks are easily set up by adjusting for a minimum s.w.r., using an s.w.r. bridge in the coaxial line between the exciter and the transmitter input, with the exciter set at a frequency in the middle of the desired band. All power to the amplifier, including filament supply, is turned off while making this adjustment. This arrangement for feeding grids makes it almost impossible for the amplifier to become unstable. No neutralization is required, and no tuning controls are necessary. The elimination of neutralization and tuning makes the amplifier as simple as a grounded-grid stage, but with the advantage that the power gain is several times greater, and the input impedance as seen by the exciter is constant. The latter is a very desirable feature.

The output circuit is the conventional pi network designed to operate into a 50- to 70-ohm

* Box 7, Wolfe City, Texas.

[1] See Peck, "Homebrew Custom Designing," *QST*, April, 1961.

[2] See Grammer, "Simplified Design of Impedance-Matching Networks," *QST*, March, April, May, 1957.

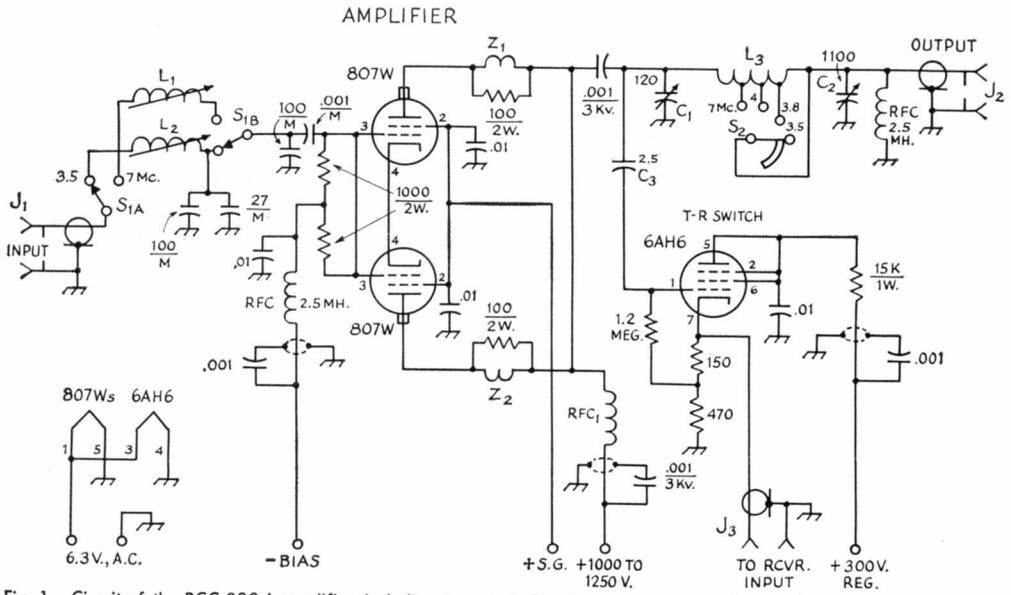


Fig. 1—Circuit of the RCC 230-L amplifier, including t.r. switch. Fixed capacitors are disk ceramic, except those marked M indicating mica. Resistances are in ohms and resistors are ½ watt unless indicated otherwise. Decimal values of capacitance are in uf.; others are in pf. ($\mu\mu$f.) unless indicated otherwise.

C_1—120- to 150-pf. 1500-volt air variable (Johnson 150F20/155-5 or equivalent).

C_2—Three-section variable, 365-pf. per section, sections in parallel (broadcast-replacement type).

C_3—See text.

J_1, J_2, J_3—Chassis-mounting coaxial receptacle (SO-239).

L_1—14 turns No. 24 enam. close-wound on ½-inch iron-core form (National XR-50 form).

L_2—30 turns No. 24 enam. close-wound on form similar to L_1.

L_3—30 turns No. 14, 1¾-inch diam., 2⅝ inches long (Pi Dux 1411A).

S_1—D.p.d.t. ceramic rotary.

S_2—Single-pole four-position progressively-shorting ceramic rotary switch (CRL P-270 index, one type PISD switch section).

RFC_1—2⅜-inch winding length No. 26 cotton-enamel wire on 1-inch ceramic insulator (Raypar RL-102 may be used).

Z_1, Z_2—5 turns No. 26 enam. wound on associated resistor.

line. A single tap on the coil is sufficient for the 40-meter band, but two tap positions, in addition to the full coil, are provided to permit maintaining a more or less constant Q across the wider 80-meter band.

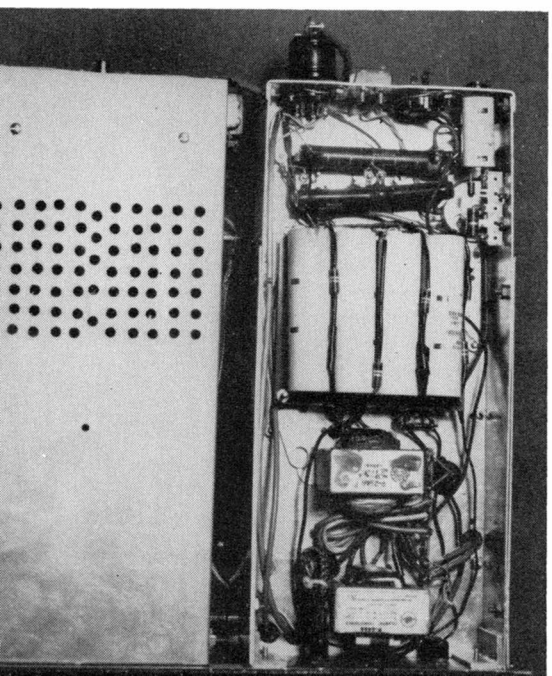
T.R. Switch

The t.r. switch uses a 6AH6 tube connected as a triode cathode follower to couple the receiver to the plate end of the final tank circuit of the amplifier. In this way, "suck-out" of the signal is avoided. The t.r. switch is built into the final, and all outlets for the filament and plate voltages are well bypassed. As a result of these precautions, no TVI has been observed. The coupling capacitor (C_3) to the grid of the t.r. switch tube is made of one inch of RG-59/U. The braid acts as one capacitor plate and the inner conductor acts as the other. The approximate capacitance is 2.5 pf.

The amplifier is metered by a grid-current meter, the full scale of which is 10 ma., and a plate meter of 300 ma., full scale. The grid meter is useful in tuning up and also acts as a modulation monitor.

The Power Supply

The circuit of the power supply is shown in Fig. 2. The cost factor indicates the use of bridge rectification so as to keep the cost of the power transformer down. After a look through current catalogs for transformers in the 1200- to 1500-volt class at 200 to 300 ma., a Merit P-3157 was



Bottom view showing the filter capacitors and two additional filament transformers in the power-supply chassis. The bottom of the amplifier chassis is perforated in the area of the 807Ws for ventilation.

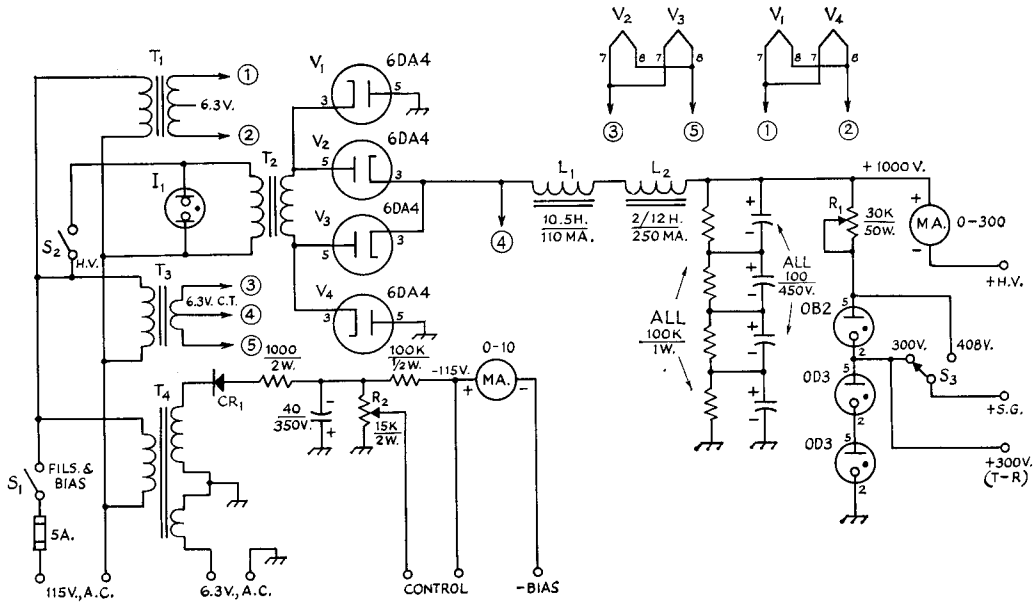


Fig. 2—Power and metering circuits. Capacitances are in μf. and capacitors are electrolytic. Resistances are in ohms.

CR_1—Silicon diode, 400 p.i.v. (Texas Inst. 1N2070 or equiv.).

I_1—NE-57 neon lamp.

L_1—Filter choke (Stancor C-1001).

L_2—Swinging filter choke (Stancor C-1402).

R_1—Slider adjustable.

R_2—Wire-wound control.

S_1, S_2—S.p.s.t. toggle switch.

S_3—S.p.d.t. rotary.

T_1, T_3—6.3-volt 3-amp. filament transformer (Stancor P-6466).

T_2—Plate transformer, 1320 volts, 250 ma. (Merit P-3157, center tap not used).

T_4—Power transformer, 120 volts, 50 ma.; 6.3 volts, 2 amp. (Merit P-3045).

selected. The transformer delivers 660 volts each side of the center tap, and is rated at 250 ma. By dropping the center tap and using bridge rectification and a choke-input filter, about 1100 volts at 250 ma. can be obtained for s.s.b. operation.[3] Past experience with this transformer has shown it to hold up well under these conditions, and it fits within the limited available space. By using heater-type rectifier tubes that have been developed for high-voltage service in TV work, we can build a bridge rectifier using only two filament transformers instead of the three usually required. Four 6DA4s were used here as they are small in size and have ample current and voltage ratings.[4]

Regulated screen voltage is obtained from VR tubes across the power supply, and a switch is used to change the screen voltage from 300 to 408 volts. Don't be afraid to operate with screens at 408 volts on s.s.b., because, when the amplifier is properly loaded, the screens are within their rated dissipation.

A separate supply provides operating and stand-by blocking bias, and also filament power for the amplifier. With the control terminals open, full supply voltage is applied to the grids of the 807s, which reduces the plate current to a negligible value. When the terminals are closed for transmission, the operating bias may be set by adjustment of the potentiometer.

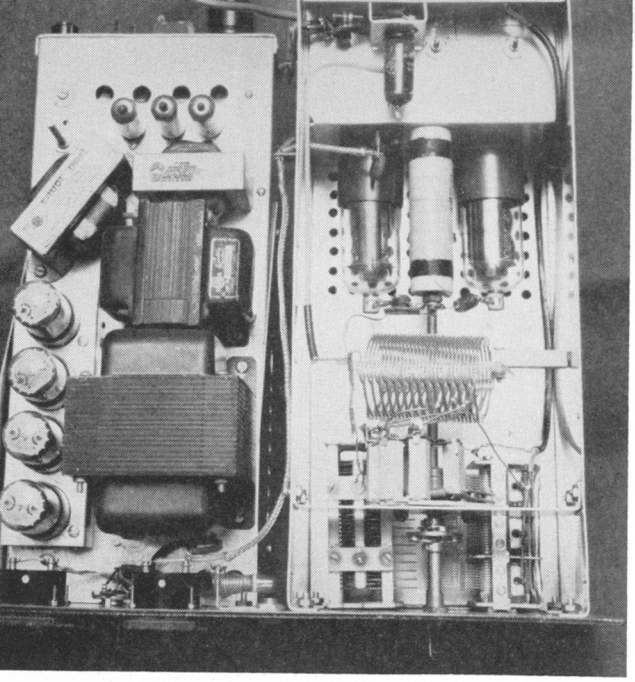
Putting the Amplifier into Operation

With all voltages, including filament, removed from the amplifier and the band switch in the 80-meter position, feed a 3.8-Mc. signal from an exciter capable of supplying about 3 watts of output to the input of the amplifier through an s.w.r. bridge. Adjust the slug in L_2 for minimum s.w.r. With the band switch in the 40-meter position, repeat the process with a signal at 7.15 Mc. Adjust the slug of L_1 for the same indication. The grid circuit is now adjusted and can be forgotten.

Remove excitation and turn on the filament and plate supplies with the screen-voltage switch set for 300 volts. Close the bias-control terminals and adjust the grid bias with the potentiometer until the plate current is just zero. Now switch the

[3] On the same basis as used by the manufacturer, the current rating would be reduced to 125 ma. when a bridge rectifier is used. However, because of the short duty cycle in c.w. and s.s.b. operation, a rating of 250 ma. for these services appears to be reasonable. The basic limiting factor is transformer temperature rise. — *Editor.*

[4] The 6DA4 has a maximum cathode-voltage rating of 300 volts negative in respect to heater. In the bridge circuit, the cathode-heater capacitances of V_1 and V_4 are in series across the transformer-secondary voltage (approximately 1850 volts peak in this case). This voltage divides equally across the two capacitances if the capacitances are equal; if they are not equal, a higher voltage appears across the smaller of the two capacitances. In this instance, the minimum peak cathode voltage, negative in respect to heater, will be 925 volts. Although the author has experienced no failures, it would seem advisable to operate V_1 and V_4 from separate heater transformers. — *Editor.*



Amplifier components are mounted inside an inverted 6 × 6 × 14½-inch homemade chassis of 0.051-inch aluminum sheet. The 807Ws and homemade plate r.f. choke are mounted on a standard 3 × 4 × 6-inch chassis which houses the grid-circuit components. The adjusting screws of the two grid coils may be seen to the right of the t.r. switch tube mounted on a bracket. The plate switch is mounted on an aluminum strip spanning the chassis below the plate coil. The grid band-switch shaft runs between the output and tuning capacitors and thence between the two amplifier tubes to the switch mounted inside the small chassis. This chassis is fitted with a cover of perforated aluminum.

Power-supply components are mounted on a homemade chassis of the same material, measuring 6 by 14½ by 2 inches. The chassis is fastened to the panel with side brackets. The rectifier tubes are mounted on a narrow inverted-U-shaped subchassis made sufficiently high that the sockets clear the main chassis. The center portion of the chassis is occupied by the high-voltage transformer, filter chokes and one of the filament transformers.

screen voltage to 408 volts and adjust the potentiometer until the plate current is 40 to 45 ma. With no load on the output and no drive, rotate the plate tank and loading capacitors through their ranges. There should be no variation in plate current, and no grid current should show.

Now, with a dummy load such as a 100- to 150-watt lamp or a doublet antenna connected to the output, and the exciter connected to the input, insert carrier and tune for resonance with the plate tank capacitor, and load with the loading capacitor for maximum output as indicated on an output indicator such as the lamp or an r.f. voltmeter. When the input is such that the grid meter begins to show a very slight amount of grid current, the plate current shou'd be in the neighborhood of 220 ma. when the amplifier is properly loaded, and the output should make a 150-watt lamp g'ow brightly. Now balance out the carrier. A sustained "ohhhh" into the microphone should cause a plate current of about 125 ma. when the grid meter shows a very slight flicker. Adjust the audio gain unt l the above conditions exist.

At this point it might be well to reinsert carrier and, with the same plate current as indicated previously (220 ma.) and the loading adjusted for maximum output, the output should fall off instantly as the excitation is lowered. If the fall-off is sluggish, slightly decrease the loading until the output falls instantly as the excitation is decreased. Again remove the carrier, and the amplifier is ready to operate on s.s.b. phone. When the p.e.p. power input is about 230 watts (1050 volts at 220 ma.), the output should be about 150 watts p.e.p. — a very respectable amount of power.

C.W. Operation

Switch the screen to 300 volts. Insert carrier until the grid draws a current of about 4 to 5 ma. when the plate current at resonance is about 150 ma. and the r.f. indicator shows maximum output. Key the exc ter and you're on c.w.

Good results should be obtained with this rig and tube life should be reasonably long with the ventilation afforded in this construction. In a similar rig using 1625s, the first pair of tubes lasted four years when operated about 10 hours a week — a total of more than 2000 hours. Tube cost was 50 cents.

I wish to thank K5BFT (Bob) for the nice decaling of the panels. If you want to hear this amplifier, look for him on the low end of the 75-meter phone band — s.s.b., of course. QST

Strays

The Metropolitan Ragchewers Club of Southeastern Michigan meets the first Sunday afternoon of each month at the Department of Recreation's Lakewood House in Detroit. It was founded three years ago and is dedicated to helping handicapped hams. Of its 100 members, about 10 are handicapped. Code and theory classes are held at the Lakewood House each Tuesday at 1930 EST. On-the-air meetings are held each Wednesday at 2100 EST on 50.250 Mc. A certificate is available through K8PUS (5336 St. Clair Ave., Detroit 13) for working 10 members (25 if you live in Michigan).

—···—

If you were ever a KR6 ham on Okinawa, please contact the Okinawa Amateur Radio Club, APO 331, San Francisco, Calif., and supply your current stateside address.

AN 811-A 200-WATT GROUNDED-GRID LINEAR AMPLIFIER

The amplifier shown in Figs. 6-56, 6-58 and 6-59 requires about 15 watts of excitation power to drive it to full peak input (200 watts) on 3.5 through 30 Mc. For convenience and compactness, the amplifier is completely self-contained; silicon-diode rectifiers in the plate and bias supplies contribute materially to the small size.

Referring to the circuit diagram in Fig. 6-57, the input impedance of the grounded-grid 811-A amplifier (about 300 ohms) is stepped down through an "L" network to offer approximately 50 ohms as a load for the driver. The network makes for little or no complication, since the circuits are fixed-tuned and, once adjusted, need not be touched again. It will be noted that on the 15- and 10-meter bands no lumped capacitance is used in the network; this is because the capacitance of the length of RG-58/U running from S_{1B} is sufficient.

The filament choke, RFC_1, is an inexpensive homemade one (described later). Since the filament winding of the power transformer has no center tap, two 22-ohm resistors are used to provide a center tap for the filament circuit. In the band-switched plate circuit, a commercial inductor (with two winding pitches) is used, and because the output capacitor is not large enough on 80 meters, on that band an additional 500 pf. is switched in by S_2.

To meter grid or plate current, a 0–1 milliammeter is used as a 0–1 voltmeter to measure the drop across 10 ohms in the grid circuit or 2.5 ohms in the plate circuit, giving 0–100 and 0–400 ma. full-scale readings respectively.

A panel operate-standby switch, S_4, removes the fixed grid bias during operate periods. If an external control is available, is in a VOX-controlled s.s.b. exciter, S_4 is left open and the external circuit connected through J_2.

All of the power is derived from a single husky TV power transformer. The plate power is derived from a voltage-doubling circuit using inexpensive silicon diodes and 450-volt electrolytic capacitors. The filament voltage for the 811-A is obtained from one transformer secondary, and another 6.3-volt secondary is utilized in a voltage-doubling circuit to provide cut-off bias for the 811-A, to avoid diode-noise problems if an electronic t.r. switch is used. High-voltage filtering is furnished by four 40-μf. capacitors connected in series.

Construction

The amplifier is built on a 10 × 12 × 3-inch aluminum chassis, with a panel and back panel of 0.063-inch aluminum measuring 9 × 12 inches. One-inch aluminum angle stock is used to make side and top lips that take the perforated-

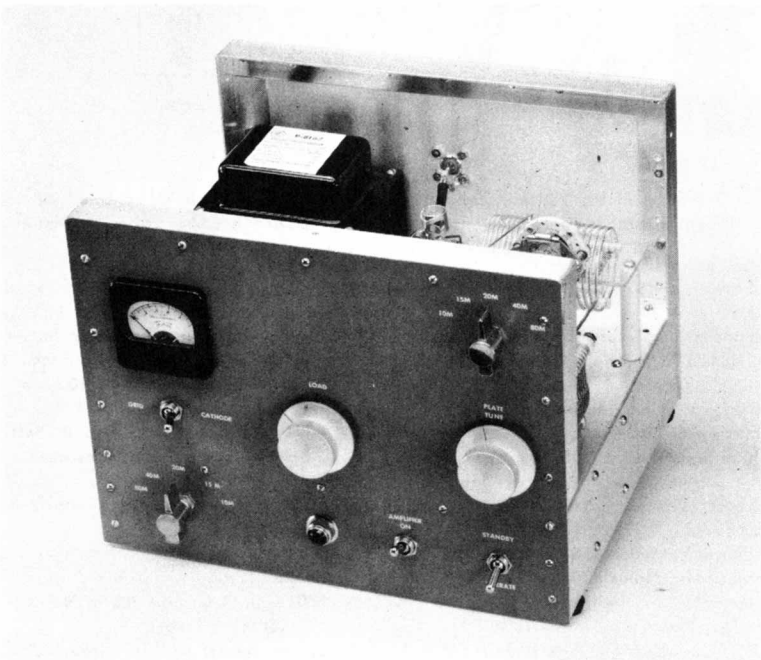


Fig. 6-56—The 200-watt grounded-grid amplifier with its perforated-metal cover removed. This compact amplifier uses an 811-A and a simple 1300-volt power supply. To simplify construction, two bandswitches are used (input at lower left, plate at upper right). The single meter can be switched to read either grid or plate current.

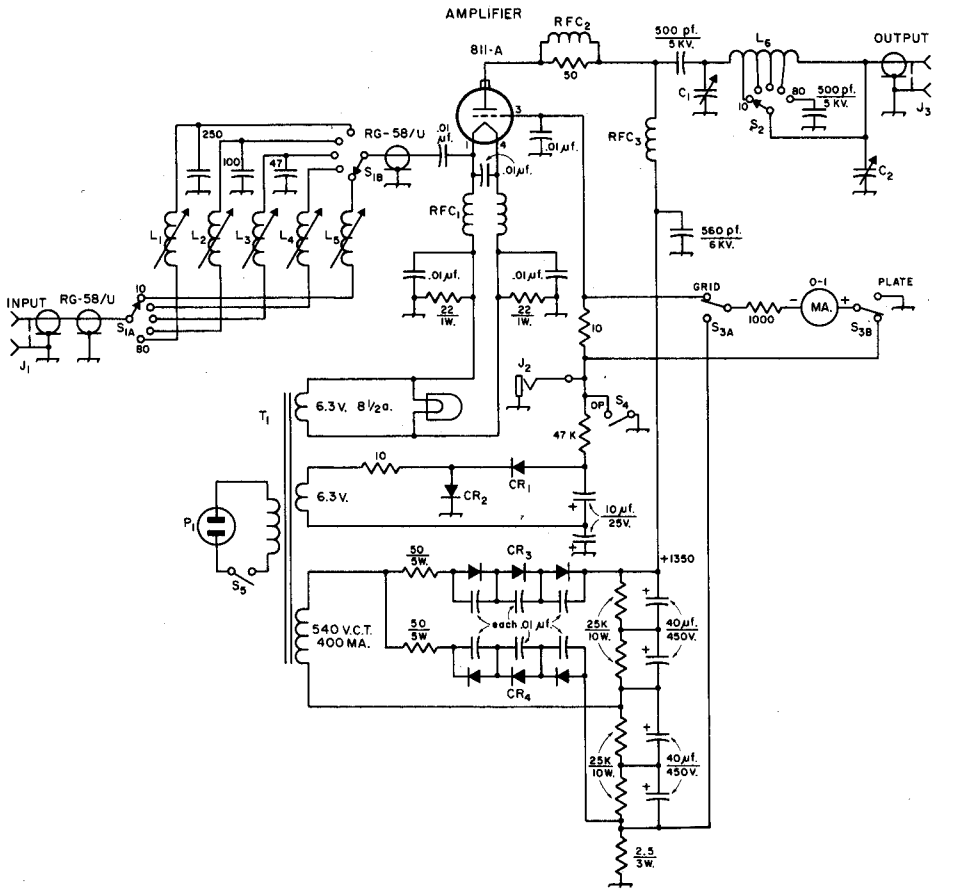


Fig. 6-57—Circuit diagram of the 200-watt grounded-grid linear amplifier. Unless specified, all capacitances are in picofarads (pf. or µµf.), all resistors are ½ watt, all resistances are in ohms. Capacitors marked with polarity are electrolytic; 0.01-µf. capacitors are 1200-volt disk ceramic.

C_1—250-pf. variable, 0.045-inch spacing (Johnson type 154-1).

C_2—3-gang capacitor, 365 pf. each section (Allied Radio 43A3522). Sections connected in parallel.

CR_1, CR_2—200 p.i.v. 750 ma. silicon (RCA 1N3253 or equiv.).

CR_3, CR_4—Each three 600-p.i.v. 500-ma. silicon diodes in series (RCA 1N3195 or equiv.).

J_1, J_3—Coaxial receptacle, chassis type (SO-239).

J_2—Open-circuit jack.

L_1—5–9-µh., adjustable (Miller 4505).

L_2—3–5-µh., adjustable (Miller 4504).

L_3, L_4—1–1.6-µh., adjustable (Miller 4502).

L_5—0.4–0.8-µh., adjustable (Miller 4501).

L_6—22 turns No. 14, 2-inch diam., 8 t.p.i. tapped 2, 3, 5, and 10 turns from C_1 end (Air-Dux Pl 1608D6).

P_1—Mounting plate a.c. plug (Amphenol 61-M1).

RFC_1—Dual winding, 29 turns No. 14 Formvar or Nylclad, spacewound on ferrite rod. See text.

RFC_2—4 turns No. 14, ⅝-inch diam., 1¼ inch long, wound outside two 100-ohm 1-watt resistors in parallel.

RFC_3—1-mh. r.f. choke (National R-154U).

S_1—2-pole 6-position rotary ceramic (Centralab PA-2003).

S_2—1-pole 6-position rotary ceramic (Centralab PA-2001).

S_3—D.p.d.t. toggle.

S_4, S_5—S.p.s.t. toggle.

T_1—560 v.c.t. 400 ma.; 6.3 v. 8.5 a.; 6.3 v. 4.5 a. (Stancor P-8167).

Knobs are Barker & Williamson 901; bar knobs are National HRB.

aluminum cover. The cover, not shown in the photographs, is a single piece 10 inches wide bent in a broad "U" shape; it is held to the lips by sheet-metal screws.

Capacitors C_1 and C_2 are fastened to the top of the chassis by 6-32 hardware; C_1 is located far enough in from the edge so that its stator will clear the cane-metal side by ¼ inch or better. The plate bandswitch, S_2, is supported by an aluminum bracket that is fastened to the rear of C_1. The 500-pf. plate-blocking capacitor and the RFC_2 assembly are supported by the top of RFC_3, and the 500-pf. 80-meter output padding capacitor is bolted to the chassis below S_2. Plate coil L_6 is supported by two 2½-inch ceramic pillars. To reduce the height taken by the 811-A above the chassis, the 811-A socket is supported below the chassis by mounting it (Amphenol 49RSS4) in a recessed shell (Amphenol 61-61).

Underneath the chassis, the two toggle switches, the 6.3-volt pilot lamp, and the bandswitch S_1 are mounted on the front lip of the chassis. The input inductors, L_1 through L_5, are clustered around the bandswitch, as are the several capacitors associated with this circuit. Lengths of RG-58/U run from the arms of S_1 to the input jack, J_1, and the 811-A socket. The unused socket pin (No. 2) is used as a tie point for the coaxial line and the 0.01-μf. coupling capacitor.

The filament choke, RFC_1, is made by winding No. 14 Formvar or Nylclad wire on a 7½-inch length of ½-inch diameter ferrite antenna core (Lafayette Radio, N.Y.C., MS-333). To obtain a high-Q coil, the two windings are wound parallel but spaced by lacing twine to give 29 turns in each coil. The coil is wound by securing the two ends and the length of spacing twine in a vise, securing the other wire ends to a 2-terminal strip held in place by a ½-inch diameter nylon cable clamp, and then winding the coils as the wires are stretched taut. Each turn of the core winds two turns of wire and one of twine. The twine is left on the coil, and no insulation is required between wires and core when the recommended surface covering (Formvar or Nylclad) is used. The choke assembly is supported below the chassis by 1-inch ceramic posts and the nylon cable clamps.

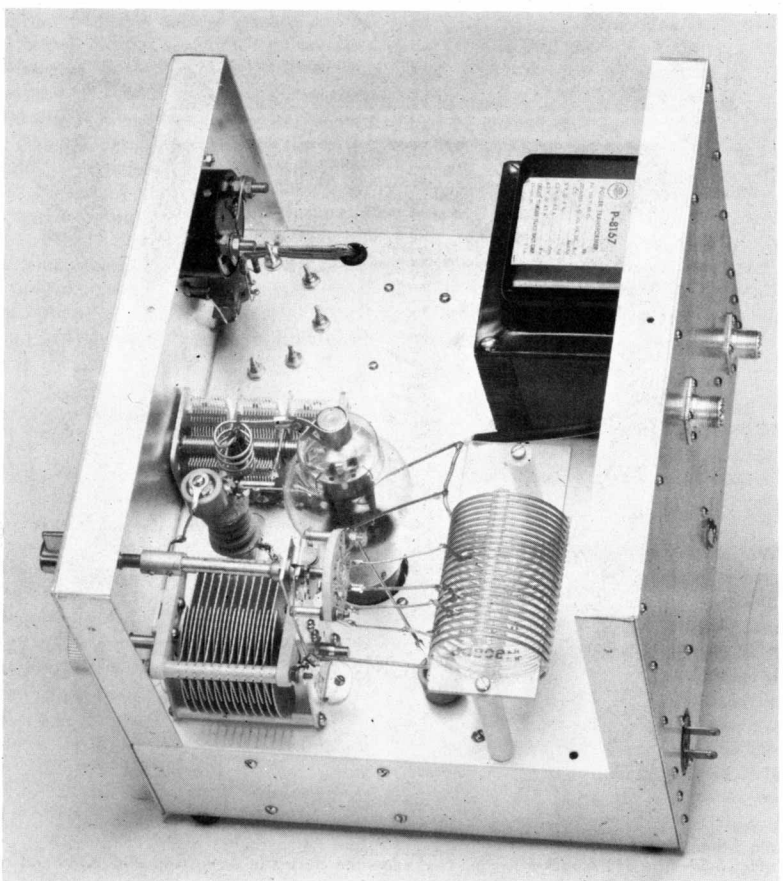


Fig. 6-58—A top view of the 811-A amplifier. The adjusting screws for the five switched input circuits project through the chassis under the meter. A bracket fastened to the back plate of the plate tuning capacitor (lower left) supports the plate bandswitch.

The bias-supply rectifiers, resistors and capacitors or mounted on a multiple tie-point strip. In the high-voltage supply, the diodes and capacitors are mounted on a 4 × 7-inch piece of 1/16-inch thick prepunched phenolic terminal board (Vector 85G24EP) with push-in terminals (Vector T-28). The resistors, both 50-ohm 5-watt and 25,000-ohm 10-watt, are mounted on tie points or narrow strips of terminal board located several inches from the diode and capacitor board. The reason for this is simple: the resistors become hot and might damage the diodes if mounted too close to them. The 2.5-ohm 3-watt resistor consists of three 7.5-ohm 1-watt resistors connected in parallel.

Tuning

When the wiring has been completed and the power supply checked (+1500 volts no-load, about 1450 with the 811-A drawing idling current of 30 ma.), the amplifier can be checked on a band with a driver capable of delivering a peak signal of 15 watts or so. A dummy load should be used during initial tests, and an output indicator (r.f. ammeter or voltmeter) is very useful. Using a c.w. signal to drive the amplifier, it should be found possible to load the amplifier so that at plate-circuit resonance the plate current is 160 ma. and the grid current is about 27 ma. As the drive is reduced the grid and plate currents should drop back at roughly the same rate. If the amplifier is not loaded heavily enough, the grid current will run proportionately higher than the plate current. There is, of course, no real substitute for a two-tone linearity test, as outlined in Chapter Eleven, but the above figures will serve as a rough guide. When the amplifier has been loaded to the figures above with a c.w. driving source, an s.s.b. signal driving it to peak output will kick the plate meter to about 80 ma. (0.2 on meter) or the grid meter to 15 ma. (0.15 on meter).

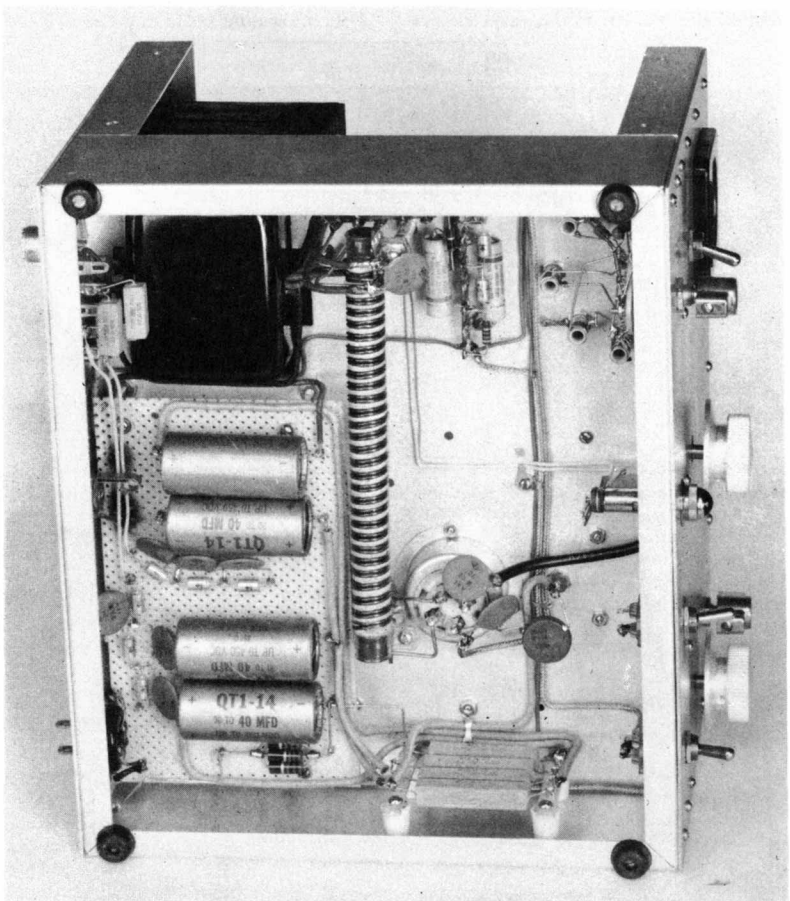


Fig. 6-59—The 811-A socket is mounted below the chassis in a recessed shell. One end of the homemade filament choke is supported near the socket, and the other end is mounted near the transformer. Four 25,000-ohm bleeder resistors (bottom) and two 50-ohm resistors (upper left) are mounted well away from the plate-supply diodes (left) and bias diodes (top center, to right of filament choke).

A COMPACT 3-400Z GROUNDED-GRID AMPLIFIER

The amplifier shown in Figs. 6-60 through 6-64 easily handles a kilowatt p.e.p. input at 3000 volts. It has been designed with ease of construction and operation in mind, and to this end as few special parts and machine operations as possible are required. Probably the major operation is adding an arm to the band switch, to ground a plate padding capacitor in the 3.5-Mc. position. This enables a smaller plate tuning capacitor to be used than would be the case if the variable were required to furnish all of the capacitance on this lowest-frequency band.

Referring to the wiring diagram in Fig. 6-61, the circuit is about as simple as it could be made. No tuned input circuit is used, since it was found that any of the s.s.b. units in the 75- to 100-watts output class could drive it without any trouble. If drive were marginal, as when only 35 watts peak were available, a coupling network might offer a slight advantage. Two r.f. chokes and a 1000-pf. bypass are used in the high-voltage lead because a high-impedance circuit like this is harder to filter than one where the current is higher and the voltage is lower. The plate coil is a standard 500-watt unit that runs cold at a kilowatt c.w. or s.s.b.

The 50,000-ohm resistor in the center tap of the filament transformer biases the tube to cut-off during "stand-by" periods and eliminates the "diode noise" caused by the static plate current. Leads to J_4 and J_5 from the VOX or other control short the resistor during transmit periods.

The connections on J_6 are similar to those on the 3-1000Z amplifier shown later in this chapter, with the exception of the lead marked "VM". This variation permits mounting the voltmeter on the transmitter panel instead of in the power supply. The power supply design is similar to that for the larger amplifier, with the exception of the power transformer (600 va.), more filter capacitance and more compact rectifiers. The smaller transformer costs 60 per cent of the larger; it is highly recommended unless one plans some day to move up to the 3-1000Z amplifier.

Front and back panels and base plate are all standard unfinished ⅛-inch thick aluminum rack panels. They are trimmed to 15 inches. The angle stock holding the pieces together, and furnishing the faces for support of the cover, are ¾ × ¾ × 1/16-inch Reynolds stock. A short piece is also used for supporting the fan, cut away as shown in Fig. 6-71.

The tube socket (Eimac SK-410) is held to the tapped base plate by long 6-32 screws. Prior to installation, one-half of the skirt is removed, so that the fan can move air under the socket and cool the pins (see Fig. 6-64). The three grid pins are grounded to individual soldering lugs.

To conserve space, the filament transformer must be modified so that the leads come out the side. This is done by removing the end bells and drilling a hole in the side through which the leads can be threaded.

To modify switch S_1, first remove the rear shaft bearing and replace the ceramic insulators with shorter (½-inch) ones. Two pairs of ⅛-inch polystyrene washers (Millen 38601) can be to expose the end of the switch shaft. A brass shaft coupling, cut to a length of 7/16 inch, is drilled and tapped 6-32 at right angles to the normal set-screw hole. The spring stock (0.20 x ⅜ silver solder) is wrapped half around the

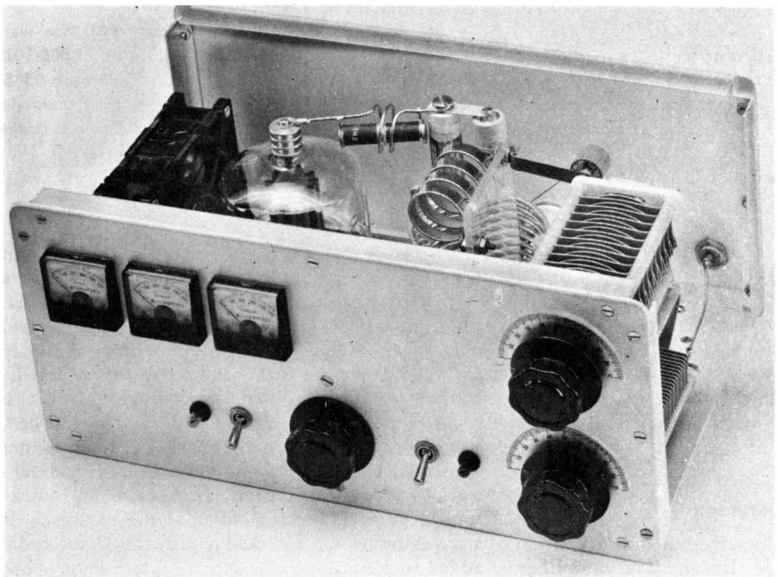


Fig. 6-60—The compact kilowatt amplifier with its perforated-metal cover removed. Using a 3-400Z in a grounded-grid circuit, it handles a kilowatt p.e.p. input at 3000 volts with ease. The (2-inch) meters monitor plate voltage, grid current and plate current. Panel is 7 X 15 inches; the bottom plate is 8¾ inches wide. (Built by Robert Smith, WILLF, Simsbury, Conn.)

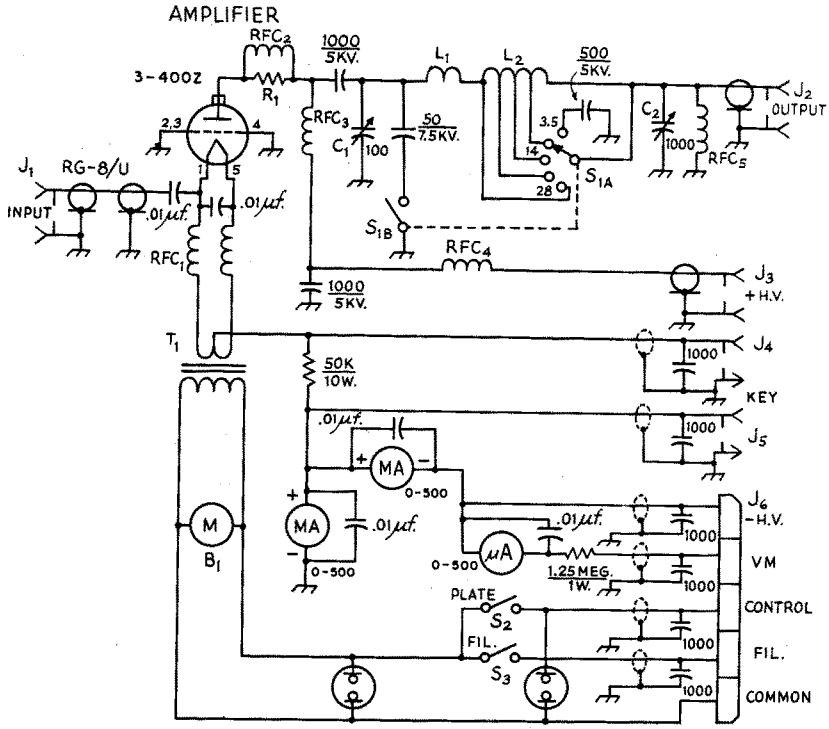


Fig. 6-61—Circuit diagram of the kilowatt grounded-grid amplifier. Unless specified otherwise, capacitances are in picofarads.

B_1—65 c.f.m. fan (Rotron Whisper, with Rotron 16415 plug-in cord assembly).

C_1—100-pf. variable, 0.125-inch spacing (Johnson 154-14).

C_2—1000-pf. variable, 0.045-inch spacing (Johnson 154-30, available direct from manufacturer).

J_1, J_2—Coaxial receptacle (Dow-Key DK-60P).

J_3—Coaxial receptacle UG-560/U (Amphenol 82-805).

J_4, J_5—Phono jack.

J_6—Octal male connector (Amphenol 86-CP8 in 61-61 shell).

L_1—4 turns ⅜-inch strap, 1⅜ diam.

L_2—20 turns No. 10, 3-inch diam. 11 turns at L_1 end, 4 t.p.i.; remainder 6 t.p.i. Tapped 1, 3, 5 and 11 turns from L_1 end. (L_1 and L_2: Illumitronics 195-1).

R_1—Two 43-ohm thermistors in series (CG 25-926).

RFC_1—24 double turns No. 14 Formvar or Nyclad, close-wound on 5¾-inch length of ½-inch diam. ferrite rod (Lafayette Radio 32 R 6103).

RFC_2—2 turns No. 14, 1¼ inch diam., 2 t.p.i., on R_1.

RFC_3—90-μh. 500-ma. r.f. choke (B & W 800).

RFC_4, RFC_5—2.5-mh. 300-ma. (National R-300U).

S_1—2-pole 6-position (5 used) heavy-duty ceramic switch (Radio Switch Corp. type 86-B, Marlboro, N.J.) See text.

S_2, S_3—Heavy-duty toggle switch.

T_1—5-v. 13-ampere transformer (Triad F-9A). See text. 50-pf. 7½-kv. capacitor is Centralab 850S-50Z. 500- and 1000-pf. 5-kv. capacitors are Centralab 858S. 1000-pf. and 0.01-μf. capacitors are disc ceramic. Meters are Simpson Model 1212. Dial lights are Drake Econoglow 117 with 100K resistor.

coupling and fastened at two points with short 6-32 screws through the new hole. The original set screw is left exposed. (Silver solder is available at welding supply houses; the type used here is called "Handy Harmon Easy Flow"). The fixed contact is supported by a ceramic insulator mounted on the base plate. "Time" the switch so that it engages as the switch is rotated from the 7- to the 3.5-Mc. position.

Adjustment

An output indicator is a useful adjunct when tuning a grounded-grid linear. The amplifier should be tested with a dummy load, to acquaint the builder with the tuning. If the drive is a steady carrier, adjust the amplifier for 330 ma. plate current (at 3000 volts) and 100 ma. grid current. If sufficient test equipment is available for the "two-tone test", this adjustment can be confirmed or modified accordingly. With a dummy load connected and with C_2 half meshed, switching to 28 Mc. and setting C_1 at minimum capacitance should give no indication of grid current (with no excitation). If there is an indication of grid current, it indicates the existence of a parasitic oscillation, and a turn may have to be added to RFC_2.

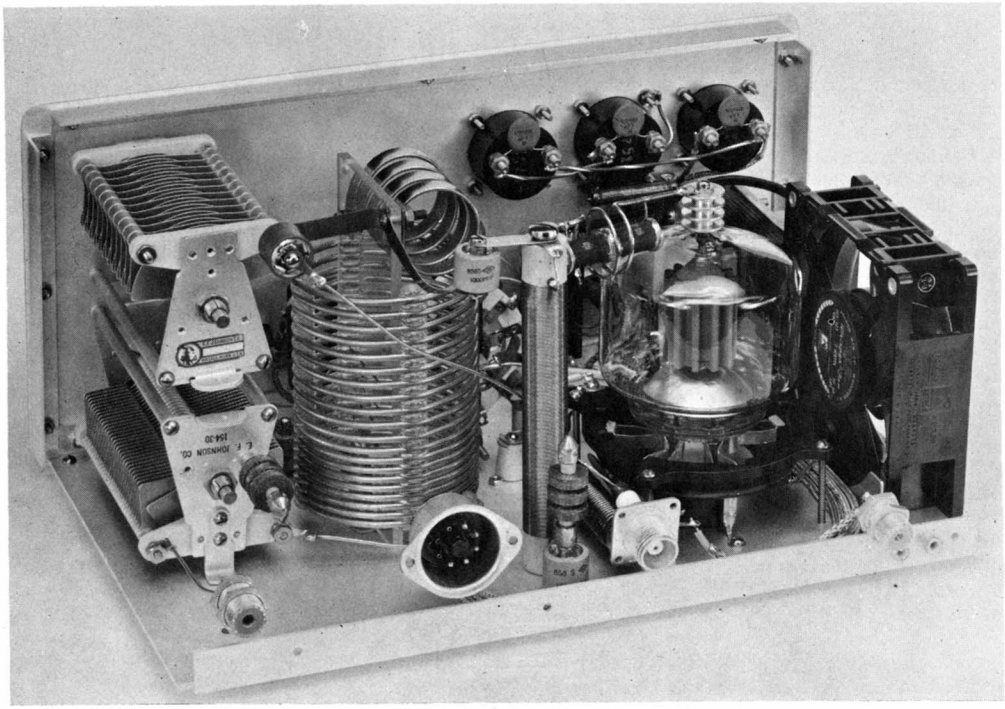
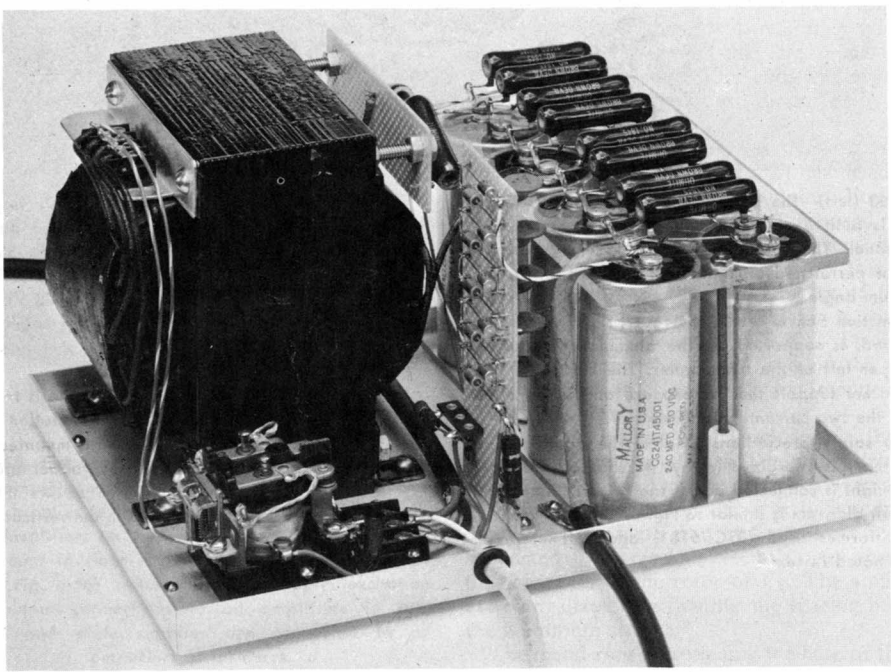


Fig. 6-62—The rear wall of the compact kilowatt has been removed to reveal the "works." Coaxial receptacles at left are output and input jacks; receptacle at center (near tube) is high-voltage connector. A 50-pf. 3.5-Mc. plate loading capacitor can be seen mounted on the plate tuning capacitor (upper left); the 500-pf. 3.5-Mc. output loading capacitor is mounted on the base behind the coil (just visible to right of variable loading capacitor).



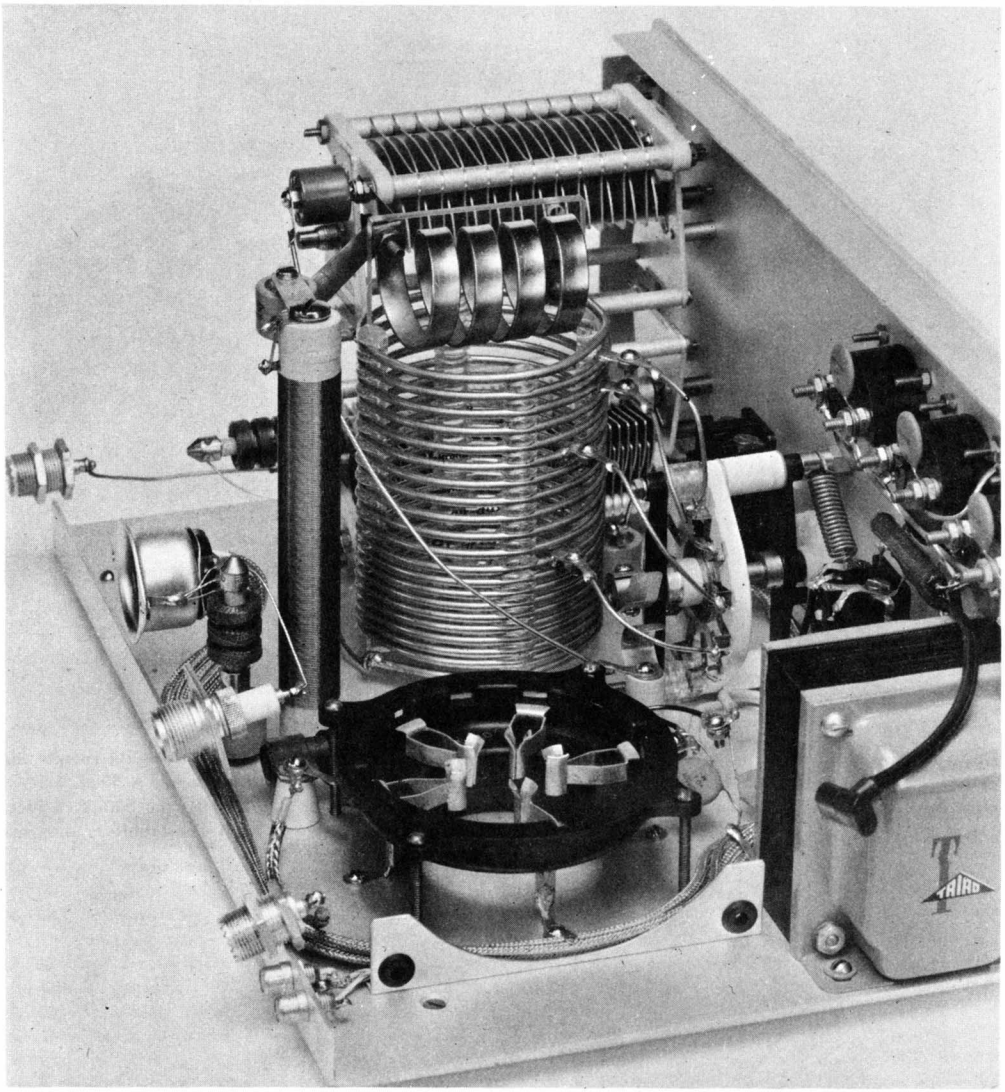


Fig. 6-63 (left)—The power supply for the 3-400Z amplifier is built on a 12-inch length of 8¾-inches high rack panel. The four sides, which take a protective cover of perforated aluminum, are made from ¾ x ¾ aluminum angle.

A junction box to which the four primary leads are connected, is supported by the aluminum bracket on the upper left of the transformer. The bolts that hold this bracket support the Vectorboard on the right that carries the two current-limiting resistors.

As a safety precaution, to alert the operator that the primary is energized (relays do stick on occasion), a pilot light is connected across the primary leads.

Circuit diagram is similar to Fig. 6-90, with exception of transformer used (BTC 6181) and voltmeter connected noted in text.

Fig. 6-64 (above)—Close-up view with the tube and fan removed discloses details of switch S_{1B}. It is made from a brass shaft coupling and a length of silver solder; in the 3.5-Mc. position it contacts a fixed arm and grounds the 50-pf. fixed capacitor (upper left).

Mounting plate for fan is trimmed away for maximum ventilation under tube socket. The fan is mounted on a piece of ¼-inch foam rubber and held in position by two screws through rubber grommets in the vertical plate.

ONE-BAND KILOWATT AMPLIFIERS

Separate kilowatt amplifiers on each of the bands 80 through 10 meters has always been the *ne plus ultra* of transmitter construction. However, space limitations and cost are the two key factors that have prevented many from realizing this goal. The amplifiers to be described are compact and are constructed economically; the builder may wish to construct one amplifier for his favorite band or the group of five for versatile all-band operation. Advantages of the separate-amplifier philosophy include optimum circuit Q for every band, simplified construction and band switching, less chance for tube failure because each amplifier is pretuned, and fast band changing for the contest-minded. The supply voltages remain on all the amplifiers; only the filament and excitation power are switched to the desired final amplifier.

The availability and proven dependability of the 813 make a pair of them the logical choice for the kilowatt amplifier. A shrewd amateur should have no trouble procuring the tubes through surplus channels or by bartering with local hams.

Referring to the circuit diagram, Fig. 6-66, the amplifier control unit contains the filament, bias and screen supplies. A 3-position mode switch, S_2, selects the bias for either Class-AB_1 or -C operation, and in the third position grounds the screen grids, to limit the plate current during initial tuning. Another 3-position switch, S_1, allows the total or individual screen currents to be read. The latter position is useful in matching tubes. The high-voltage supply should furnish from 1750 to 2250 volts.

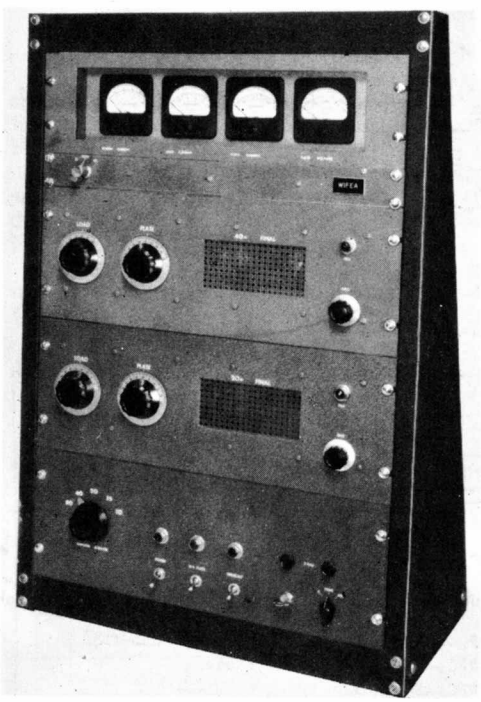


Fig. 6-65—Individual kilowatt amplifiers for two bands plus complete metering and all control circuits and power supplies (except plate) fit handily into a table rack. Amplifiers for five bands plus the plate supply will mount in floor rack. Band switch at lower left (S_8 in Fig. 6-66) switches filament supply, excitation and output connections to all amplifiers in use; screen and plate supplies are connected to all amplifiers at all times.

Construction

Each amplifier is assembled on a 13 × 17-inch aluminum bottom plate. Two 5 × 13 × 3-inch aluminum chassis are used as the sides of the enclosure. The paint is removed from the back of a 7-inch aluminum rack panel, and a piece of Reynolds cane metal is sandwiched between the panel and the two chassis. A rectangular window in the panel provides additional ventilation and a means for inspecting the color of the tube plates. The top and back of the enclosure are formed from a single piece of cane metal, bent to fit the chassis rear and top. Three lengths of 1 × 1 × ⅛-inch aluminum angle stock are used in the corners of the enclosure, as can be seen in Figs. 6-81 and 6-82.

The variable tank capacitors, C_4, are mounted on 1-inch stand-off insulators, to bring the shafts to the proper panel height. In the 10-meter amplifier the capacitor shaft must remain above r.f. ground, and a suitable insulated shaft coupling is used. On the other bands, the rotors of the capacitors are grounded to the chassis through metal straps.

On 20, 15 and 10 meters the tank coils are wound self-supporting of ¼-inch diameter soft-drawn copper tubing, and they are supported by their leads. On 80 and 40 the coils are lengths of Air-Dux stock, and they are supported by small ceramic insulators.

The special plate r.f. chokes, RFC_2, are constructed by close-winding No. 24 enameled wire on ¾-inch diameter ceramic insulators. Four-inch long insulators (National GS-4) are used on the 80- and 40-meter bands, and 2-inch long insulators (National GS-3) are used on the other bands. In each case the original base of the insulator is removed and the insulator is mounted on a stand-off (Johnson 135-20). The high-voltage lead and the "cold" end of the choke are connected to a soldering lug mounted between the two insulators.

Bridge neutralization is included in the 20-, 15- and 10-meter amplifiers. The neutralizing capacitors are made from two ½-inch wide aluminum strips 5 inches long. One strip is connected directly to the plate lead at C_3 and the other is supported by a ceramic feed-through insulator that connects to the rotor of C_1. The amplifiers are neutralized by adjusting the spacing between the aluminum strips.

The metal ring surrounding the base of the 813

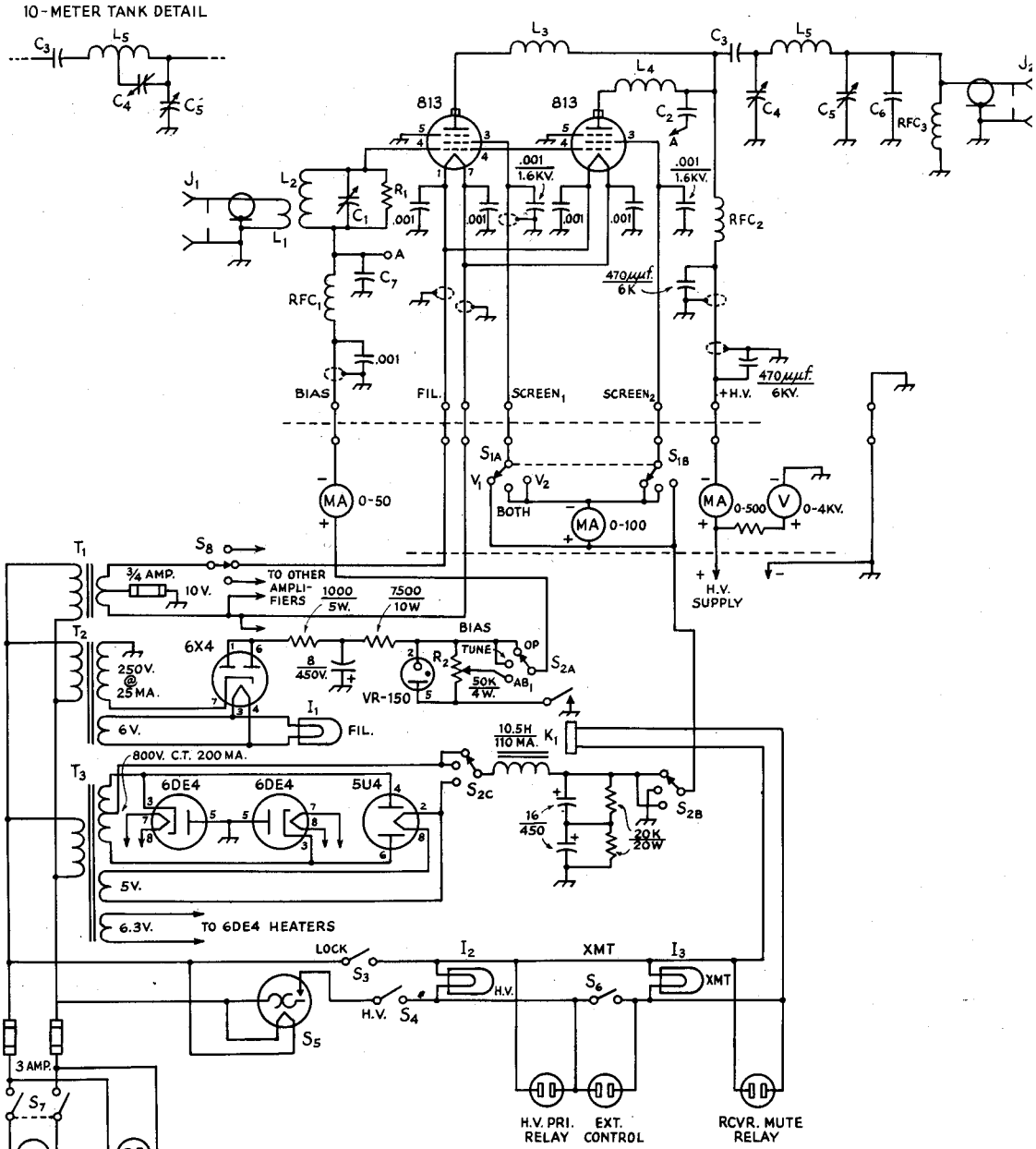


Fig. 6-66—Circuit diagram of a single parallel-813s amplifier and the control section. Diagram of each amplifier is similar, except as noted below. Unless specified otherwise, capacitances are in μf., capacitors marked with polarity are electrolytic, fixed capacitors are ceramic, resistances are in ohms.

C_2—Not used on 80 or 40 meters; see text.

C_3—Two 500-pf. 20-kv. ceramic (Centralab TV-207) in parallel on 80 m.; single 500-μμf. 20-kv. ceramic on other bands.

C_7—0.001-μf. 1-kv. ceramic on 80 and 40 m.; 240-pf. silver mica on other bands.

I_1—6-v. pilot lamp.

I_2, I_3—115-v. pilot lamp.

J_1, J_2—Coaxial cable receptacle.

K_1—S.p.d.t. relay, 115-v. a.c. coil.

L_2, L_4—Not required on 80 or 40 m.; 6 turns No. 14 on 1/4-inch diam.

R_1—10,000 ohms, 2 watts, composition.

R_2—50,000 ohms, 4 watts (Mallory M50MPK).

RFC_1—2.5-mh. 75-ma. r.f. choke.

RFC_2—See text.

RFC_3—2.5-mh. 300-ma. r.f. choke.

S_1—Two-pole 3-position rotary switch, shorting type.

S_2—Two-pole 3-position rotary switch, non-shorting type.

S_3—S.p.s.t. lock switch (AHH 81715-L).

S_4, S_6—S.p.s.t. toggle.

S_5—Time delay relay (Amperite 115N060).

S_7—Heavy duty d.p.s.t. toggle.

T_1—10-volt 10-ampere filament transformer.

T_2—250-volt 25-ma. transformer (Stancor PS-8416).

T_3—800-v.c.t. 200-ma., 5- and 6.3-v. heater windings.

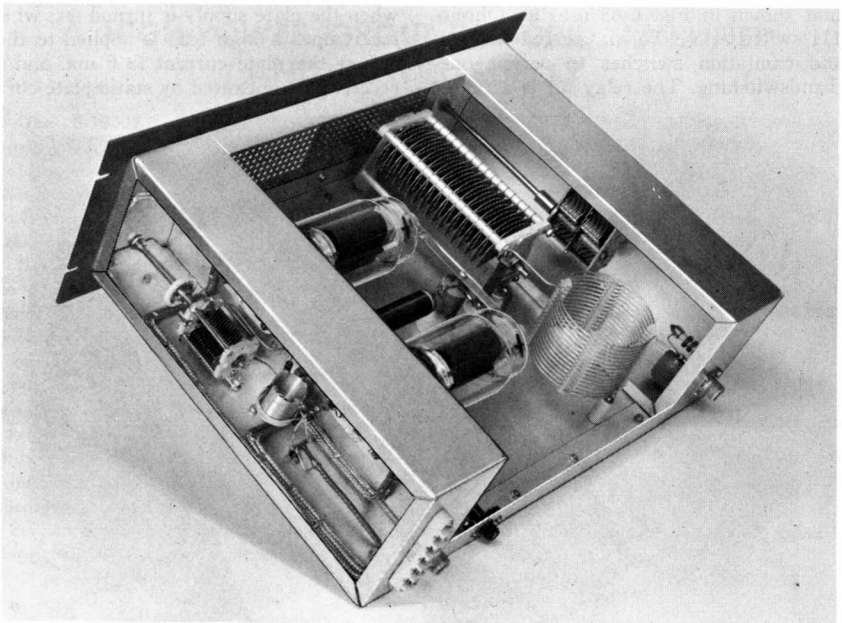


Fig. 6-67—View of the 80-meter amplifier with its cane-metal covering removed. As in each amplifier, the chassis is made from two 5 × 13 × 3-inch chassis and a 13 × 17-inch base plate. Input and low-voltage leads make up to terminals and jack in center foreground.

should be grounded to the chassis. A piece of Eimac Finger Stock or a homemade contact can be used for the purpose.

All power wiring is done with shielded wire and bypassed as described in Chapter Twenty-three. The filament leads should be made from No. 14 (or heavier) shielded wire.

The screen and bias supplies plus station control circuits are built on a rack-mounting chassis (Bud CB-1373) behind a 7-inch panel. In the Class-C position of S_2, +400 volts is applied to the screens and —150 is connected to the grids. In the Class-AB_1 position, the screen voltage is increased to 700 and the grid bias is dropped to a value determined by the setting of R_2. This latter setting should be one that gives best linearity without exceeding a no-signal plate input of 150 watts for the two 813s; it depends on the plate voltage available. A heavy bleed on the screen supply helps the regulation.

Coil and Capacitor Table

Band	80	40	20	15	10
C_1	100 μμf. (Johnson 100L15)	100 μμf. (Johnson 100L15)	50 μμf. (Johnson 50L15)	50 μμf. (Johnson 50L15)	50 μμf. (Johnson 50L15)
C_4	150 μμf. (Johnson 150E45)	150 μμf. (Johnson 150E45)	35 μμf. (Johnson 35E45)	35 μμf. (Johnson 35E45)	50 μμf. (Hammarlund MC-50-MX)
C_5	710 μμf. (2-gang 365 μμf.)	325 μμf. (Hammarlund MC-325-M)	325 μμf. (Hammarlund MC-325-M)	325 μμf. (Hammarlund MC-325-M)	325 μμf. (Hammarlund MC-325-M)
C_6	500 μμf. (Centralab TV-207)	100 μμf. (CRL 850S-100N)	—	—	—
L_1	4 t. No. 22*	3 t. No. 22*	2 t. No. 22*	1 t. No. 22*	1 t. No. 22*
L_2	32 t.p.i. No. 24, 1 inch long, 1 inch diam. (B&W 3016)	16 t.p.i. No. 20 1¼ inch long, 1 inch diam. (B&W 3015)	8 t.p.i No. 18 1⅜ inch long, 1 inch diam. (B&W 3014)	8 t.p.i. No. 18 ¾ inch long 1 inch diam. (B&W 3014)	8 t.p.i. No. 18 ½ inch long, 1 inch diam. (B&W 3014)
L_5	6 t.p.i. No. 12, 3 inch long, 3 inch diam. (Air Dux 2406)	4 t.p.i. No. 12, 3¾ inch long, 2½ inch diam. (Air Dux 2004)	2 t.p.i. ¼-inch copper tubing, 4½ inch long, 2½ i.d.	2 t.p.i. ¼-inch Copper tubing, 3 inch long, 2½ i.d.	2 t.p.i. ¼-inch copper tubing, 2 inch long, 2½ i.d. C_4 tap 2 turns.

* Insulated hookup wire, wound over C_7 end of L_2.

The unit shown in Fig. 6-65 uses an Ohmite Model 111 switch at S_8. This is ganged with antenna and excitation switches to permit one-control bandswitching. The relay K_1 is actuated when the plate supply is turned on; when the relay is open a high bias is applied to the 813s to reduce the plate current to 0 ma. and eliminate receiver noise caused by static plate current.

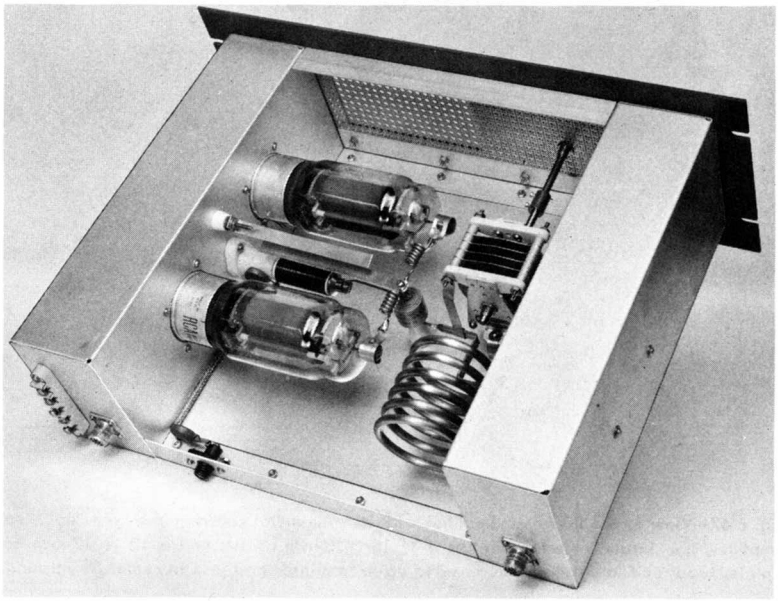


Fig. 6-68—Top view of the 15-meter amplifier. The neutralizing capacitator consists of two strips of aluminum, supported by the plate-blocking capacitor and a feedthrough insulator. It is mounted over the r.f. choke between the two 813 tubes.

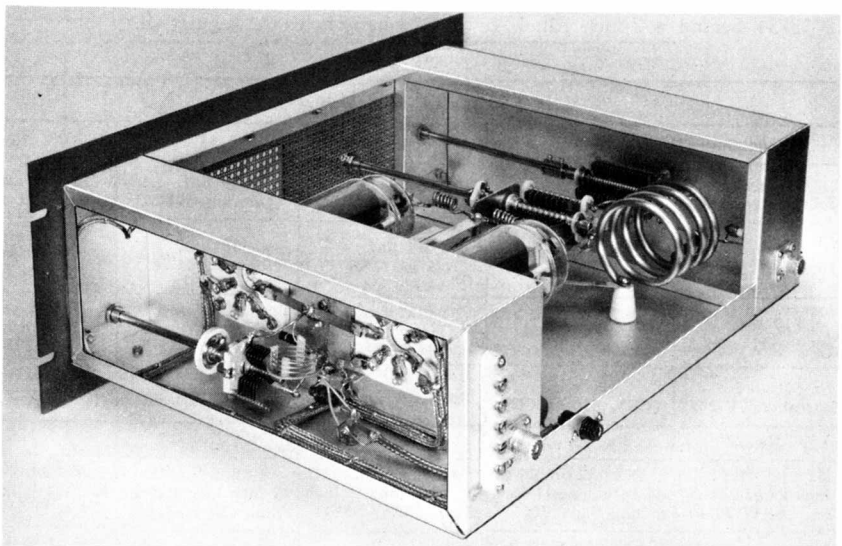


Fig. 6-69—As in the other amplifiers, the 10-meter final uses shielded wires in the filament, screen, and grid-return circuits. For tuning this amplifier uses a small variable capacitor connected across half of the plate coil, to maintain a favorable *L*/*C* ratio.

A HIGH-POWER GROUNDED-GRID AMPLIFIER AND POWER SUPPLY

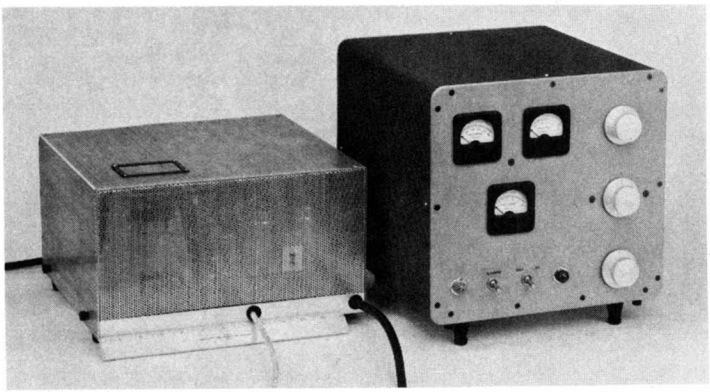


Fig. 6-70—The 3-1000Z grounded-grid linear and its solid-state power supply are shown here with a 12-inch rule to show the relative sizes of the units. The chart frame on the top of the power-supply housing holds the clear plastic through which the voltmeter can be read. The amplifier is mounted on short legs to allow air to be drawn in at the bottom and blown up past the tube. The meters indicate grid (left) and plate current and relative output (below). Knobs at right (B & W 901) control plate (top), band switching and loading. (Built by Robert Smith, W1LLF.)

The grounded-grid linear amplifier and power supply shown in Fig. 6-70 are designed for the amateur power limit in single-sideband operation. The amplifier uses a 3-1000Z triode to handle a p.e.p. input of 2 kw. on peaks. The amplifier and supply each occupy just over 1 cubic foot and are made from readily available components. The 3-1000Z requires a driver capable of supplying at least 65 watts p.e.p.

Referring to the amplifier circuit diagram in Fig. 6-84, the grid of the triode is grounded for both r.f. and d.c. The cathode is maintained above r.f. ground by feeding it through a homemade filament choke wound on a ferrite rod. Although the input impedance of the grounded-grid 3-1000Z is close to 50 ohms and would provide a good match for a driver with fixed-impedance output, a pi network input circuit, $C_1C_2L_1$ is used to supply some Q to the circuit, for better linearity. The Q is low, however, and once adjusted an input circuit requires no further attention for operation anywhere within its band. For simplicity in the circuit diagram, only one set of capacitors and inductor is shown in Fig. 6-84.

The plate tank circuit uses a commercial coil assembly (Air Dux 195-2) that has been rearranged to conserve space and fit better into the compact package. The bandswitch is made from the products of two different companies, ganged together to provide an input-circuit 2-pole switch and a plate-circuit single-pole switch. The plate-circuit switch is modified slightly, as described later, to permit the switching in of a plate loading capacitor on 75 meters.

During "receive" periods a 50,000-ohm resistor in the filament-transformer center tap practically cuts off the plate current; leads from it are brought to two phone jacks so that the resistor can be shorted out during "transmit" by a set of contacts on the antenna transfer relay (or by the VOX control if an electronic t.r. switch is used).

Three meters are used in the amplifier. The grid and plate currents are read separately by a 0–500 milliammeter and a 0–1 ammeter. The third meter is a relative-output indicator metering the r.f. voltage at the output. D.c. for the meter is derived from a germanium-diode rectifier connected to a resistive r.f. voltage divider.

Panel switches and associated neon indicators are provided for control of the filament (and blower) and high-voltage power.

Construction

Two identical pieces of ⅛-inch thick aluminum, 11¼ inches high and 12¼ inches wide, are used for the front panel and the rear plate. These may be cut from 12¼-inch rack-panel material (Bud SFA-1837) if no other source is available. The major chassis that supports the tube socket and the filament transformer is a standard one measuring 7 × 12 × 3 inches (Premier ACH-433). It is held to the front panel by the two toggle switches and the two indicator lamp housings (Dialco 951308X) and to the rear panel by the 25,000-ohm variable resistor in the output-metering circuit and various screws that hold J_1, J_3 and J_6 in place (see Fig. 6-73). The plate choke, RFC_3, is mounted on this chassis, with a 1000-pf. 5-kv. ceramic capacitor (Centralab 858-S) near its base; the high-voltage lead is brought from the base of the r.f. choke (and from the capacitor) through the chassis in a ceramic feedthrough insulator. The output-indicator circuitry, consisting of the 22,000- and 470-ohm resistors, the 1N34A rectifier and the 0.001-μf. capacitor, is also mounted on the chassis (see Fig. 6-75). These are mounted on a multiple tie-point strip fastened to the top edge of the chassis near C_4. The assembly is shielded by a 2¾ × 2⅛ × 1⅝-inch "Minibox" (Bud CU-3000-A).

The input circuitry and S_{1A} and S_{1B} are housed in a 4 × 4 × 2-inch aluminum case (Premier

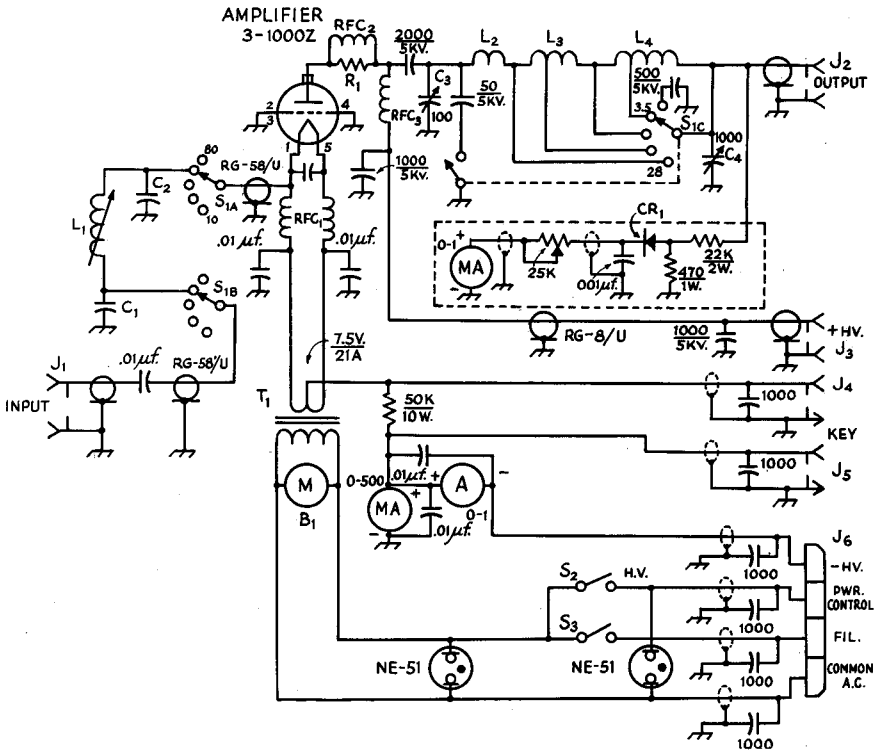


Fig. 6-71—Circuit diagram of the 3-1000Z amplifier. Unless specified otherwise, capacitances are in picotarads (pf. or μμf.).

B_1—65 c.f.m. fan (Rotron "Whisper").
C_1, C_2—See L_1 Coil Table
C_3—100-pf. variable, 0.125-inch spacing (Johnson 154-14).
C_4—1000-pf. variable, (Johnson 154-30, buy direct).
CR_1—1N34A or equivalent.
J_1—Coaxial receptacle, SO-239.
J_2—Coaxial receptacle (Dow-Key DK-60P).
J_3—Coaxial receptacle, UG-560/U (Amphenol 82-805).
J_4, J_5—Phono jack
J_6—Octal male connector (Amphenol 86-CP8 in Amphenol 61-61 shell).
L_1—See L_1 coil table.
L_2—4 t. 5/16-inch strap, 1½-inch diam., 2 t.p.i.
L_3—4 turns ¼-inch tubing, 3-inch diam., 2 t.p.i. Tapped 1¾ turns from L_2 end.
L_4—16 turns No. 8, 3¼-inch diam., 4 t.p.i. Tapped 7 turns from L_3 end.
L_1, L_2 and L_3 are parts of commercial kilowatt coil assembly (Air-Dux 195-2).
R_1—Two 35-ohm "Thermistors" in series (GC 25-918).
RFC_1—28 double turns No. 10 Formvar or Nylclad, closewound on ½-inch diam., 7½-inch long ferrite rod (Lafayette Radio, N.Y.C., 32 R 6103).
RFC_2—2 turns No. 10, 1¼-inch diam., 2 t.p.i., on R_1.
RFC_3—90-μh. 500-ma. r.f. choke (B & W 800).
S_1—2-pole 6-position (5 used) ceramic rotary switch (Centralab PA-2003) ganged to 1-pole 6-position (5 used) heavy-duty ceramic switch (Communications Products 86-B, Marlboro, N. J.). See text.
S_2, S_3—S.p.s.t. toggle.
T_1—7½-volt 21-ampere filament transformer (Stancor P-6457). Meters are Simpson Model 127; 1000-pf. 5-kv. capacitors are Centralab 858-S; 50-pf. 5-kv. capacitor is Centralab 850S.

AC-442) held to the main chassis by two ¼-inch panel bearings; the RG-58/U leads to the switches are run through the holes in the bearings. The switch section is mounted on one removable plate of the case; the other plate is not used.

To conserve space and to provide a shaft extension for ganging, switch S_{1C} must be modified slightly. This is done by removing the rear shaft bearing and replacing the two ceramic insulators with shorter (⅝-inch long) ones. If suitable insulators cannot be found in surplus (8-32 tapped holes are required), they can be machined from suitable insulating material. When the rear bearing is replaced, it should first be reversed. The combination of reversing the rear bearing and using a shorter pair of insulators leaves enough shaft extending to take a flexible shaft coupling (Millen 39005). This coupling is connected to a similar coupling on S_{1A-B} through a length of ¼-inch diameter insulating rod.

To provide an extra grounding contact, switch S_{1C} must be further modified. A brass collar that

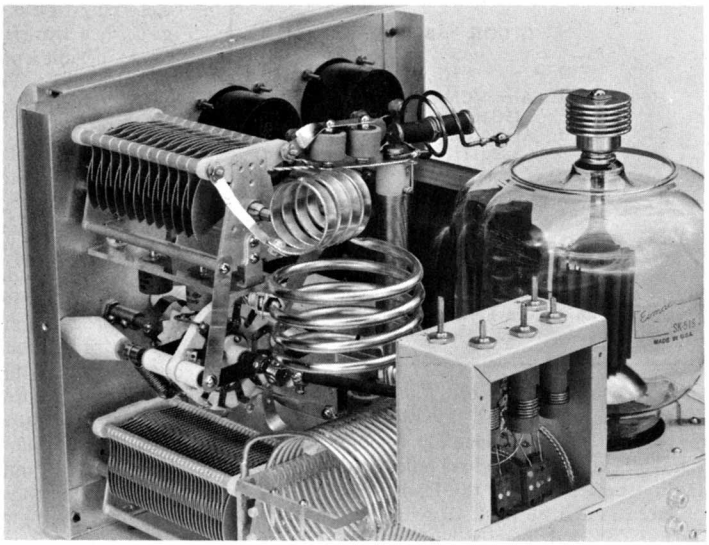


Fig. 6-72—Rear view of the 3-1000Z amplifier with the back wall removed. Note the two ceramic capacitors mounted on the plastic strip below the plate tuning capacitor (top left). The left-hand capacitor is cut into the circuit on 3.5 Mc. by the spring arm on the switch shaft (see text).

will fit the shaft is required. It is drilled and tapped to fasten to the shaft and also to hold a strap made of spring material (silver solder ribbon, 0.020 × ¾ inch was used, trimmed to the width of the collar). The strap is located on the shaft so that in the 3.5-Mc. position it will contact the 100-pf. 5-kv. ceramic capacitor supported by a strip of plexiglas hung from C_1 (see Fig. 6-72). The switch is supported on the panel by four 1-inch high ceramic cone insulators (Johnson 135-501) mounted base-to-base. On the panel, shaft bearings are used for the switch shaft and the two capacitor shafts.

The tank coil assembly is modified by first removing the strap coil and the copper tubing coil from the polystyrene strip that supports them. Then saw a 3-inch long strip from one end and mount it at right angles to the original strip with cement or brass screws (see Fig. 6-72). Coil L_4, the wire coil, is supported by the polystyrene strip, which rests on the bottom plate at the outside and on the basic chassis on the inside. The inside end of L_4 is bent up and a loop formed in the end. Coil L_3 is bolted to this loop with a brass 8-32 machine screw, and the tap running to the 20-meter pin on the switch is taken off at the same junction. All coil taps were made of 5/16-inch wide straps cut from copper flashing. The coil L_2 is supported at one end by an end of L_3 and at the other by a copper strap fastened to the stator of C_3 (see Fig. 6-75).

Two 1000-pf. 5-kv. capacitors and the parasitic suppressor, RFC_2R_1, are supported by the top of RFC_3, and a flexible strap runs from the other end of the parasitic suppressor to the plate cap. To avoid contact between the cap and the amplifier cover, two layers must be cut off the top of the plate connector (Eimac HR-8).

The chimney (Eimac SK-516) is held in place around the 3-1000Z by four metal clips, and the socket (Eimac SK-510) is modified slightly as mentioned in the caption for Fig. 6-86. The blower is mounted on the 12 × 11¼ × ⅛-inch bottom plate so that it is not directly under the tube socket but near the front panel. Rubber (they could be turned wooden) feet attached to the bottom plate support the amplifier above the operating table and allow the free flow of air into the blower.

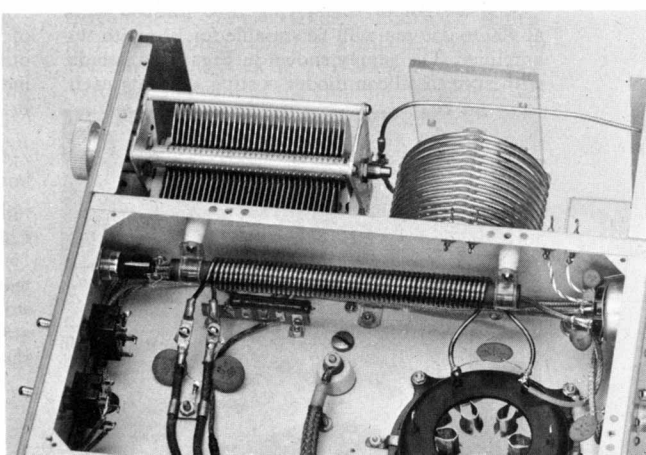


Fig. 6-73—A view under the sub chassis of the amplifier. The filament choke can be seen supported off the side wall by ceramic stand-off insulators and plastic cable clamps. A lip on the tube socket (right foreground) has been removed to provide more space and better air flow; the three grid pins of the socket are grounded to the chassis by short straps. Don't try to bend the terminals out of the way before sawing off the lip; remove them entirely.

The resistor mounted on a tie-point strip and visible under the left end of the filament choke is the 50,000-ohm cathode resistor used for stand-by bias; leads from it run in shielded wire to J_4 and J_5. Wires and plug dangling over the side run to the blower (see Fig. 6-87).

The jack on the rear wall closest to the near side (foreground) is J_3, the high-voltage cable jack. A 1000-pf. 5-kv. capacitor is mounted on the chassis just inside this point.

L_1 COIL TABLE

Band	C_1, C_2	L_1
80	1600 pf. (Arco VCM-35B162K)	16 t., closewound
40	910 pf. (Arco VCM-20B911K)	8 t., closewound
20	430 pf. (Arco VCM-20B431K)	6 t., closewound
15	300 pf. (Arco VCM-20B301K)	4 t., closewound
10	220 pf. (Arco VCM-20B221K)	4 t., spaced to fill form.

Capacitors are 1000-v. silver mica. Inductors wound with No. 16 Formvar or Nylclad on ½-inch diam. slug-tuned form (National XR-50).

To conserve space, the filament transformer T_1 must be modified so that the leads come out the bottom. This is done by removing the end bells, blocking the original holes with paper and drilling new holes for the leads.

There is a little trick to winding the filament choke, RFC_1, primarily because the wire is so heavy that it cannot be wound directly on the ferrite rod without springing out. To overcome this, the dual winding of the choke is wound first on a length of 7/16-inch wooden dowel. When it is released it will spring out slightly, enough to permit it to be slipped off the dowel and on to the ferrite core. One-half inch nylon cable clamps mounted on 5/8-inch standoff insulators hold the core in place on the inside wall of the chassis (see Fig. 6-73). Formvar or Nyclad wire is recommended for the choke because with it there is very little chance that the insulation will be chipped off as the core is inserted in the coils.

It will be noted that the three grid leads are connected directly to the chassis. There are slots in the SK-510 socket especially provided to allow low-inductance ground terminations to be made to each of the grid terminals. The grounding straps are slipped through the slots and soldered to the socket pins.

The 7 × 7 × 2-inch chassis that shields the three meters is held to the panel by a single screw that threads into a metal stud. To clear the shielded wires running up to the meters from the hole in the main chasis, a suitable slot is cut on one side of the shield chassis.

Power Supply

A power supply delivering 2500 to 3000 volts at 400 to 350 ma. will be suitable for use with the amplifier. The supply shown in Figs. 6-76 is built with sixteen silicon diodes costing 85 cents each.

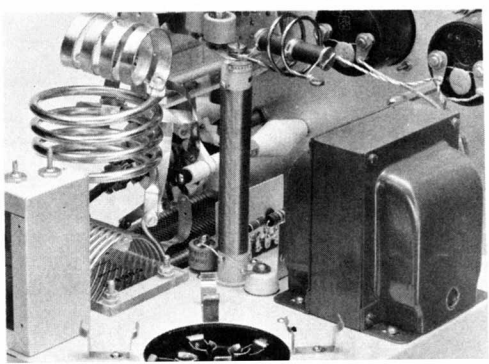


Fig. 6-75—Another view of the grounded-grid amplifier, showing the output voltmeter (shield cover removed) components mounted on a multiple tie point strip. The metal stud between the meters receives the screw that holds down the meter shield (7 X 7 X 2-inch chassis).

Referring to the circuit diagram of the supply, Fig. 6-77, a transformer with a dual primary is used, to permit operation from either a 115- or a 230-volt line. The higher voltage is recommended. No fuses are shown; it is expected that the supply will be protected by the fuses (or circuit breakers) in the wall outlet box.

The filter capacitors are called "computer grade" capacitors; the 25K resistors across them serve both as the bleeder resistor and the equalizing resistors. In operation, the idling current of the amplifier (180 ma.) further bleeds the supply. The 0-5000 voltmeter is included to comply with the FCC regulations. It is a good idea to get into the habit of watching the voltage decay when the power supply is turned off; in this way you are less likely to get mixed up with a residual charge in the capacitors. An interlock switch in series with the relay makes it necessary to replace the cover before turning on the supply.

The 10-ohm resistor between the negative terminal and chassis allows plate-current metering in the negative lead with no difference in potential between power-supply and amplifier chassis.

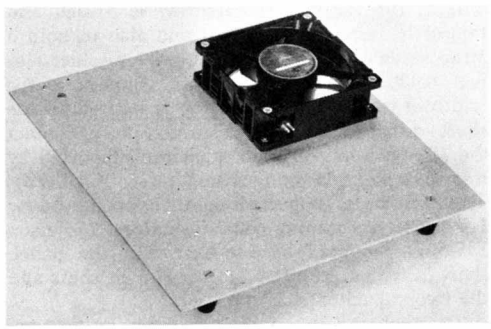


Fig. 6-74—Blower is mounted on bottom plate of amplifier near the front panel (not directly under the tube). A.c. power connector for blower is stock item (Rotron 16415).

The power supply construction is not critical, and the main considerations are adequate insulation and safety precautions. The string of silicon diodes and their associated capacitors and resistors are mounted on a 3 × 9¼-inch strip of prepunched terminal board (Vector 85G24EP), with push-in terminals (Vector T28) serving as tie points. The rectifiers are mounted on one side of the board, the resistors and capacitors on the other. The strip is mounted on the 12 × 13 × ⅛-inch aluminum base plate with a pair of panel brackets (Raytheon MB-128).

The pair of 50-ohm resistors is mounted on a 7½ × 1¾-inch strip of pre-punched terminal board, supported by two ¼-20 bolts, 5 inches

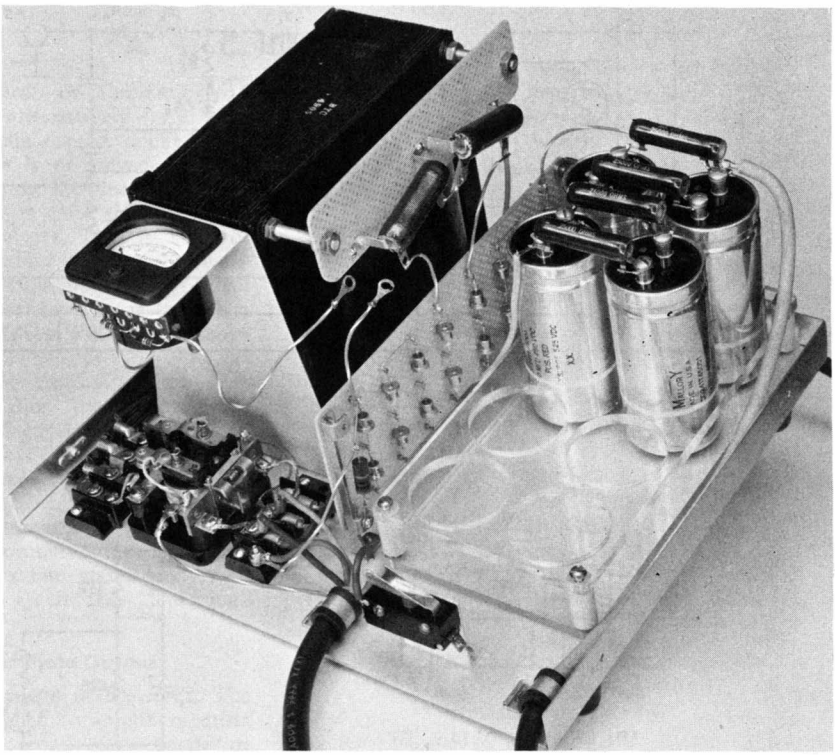


Fig. 6-76—In this view of the power supply, four filter capacitors have been removed to show how the silicon diodes are mounted on one side of the terminal board; equalizing resistors and capacitors are mounted on the other side. The meter mounting bracket is held to the base plate by two of the bolts that run through the feet of the transformer. Small switch in the foreground is the interlock; control relay is mounted on base plate to left of terminal block.

long, that replace two of the original transformer bolts. This strip also serves as a stop to prevent the cover and the resistors coming in contact.

The bank of eight 240-μf. capacitors is insulated from the base plate by a sheet of $4\frac{3}{4} \times 9 \times \frac{1}{4}$-inch clear plastic (Lucite or Plexiglas). A similar sheet with clearance holes is mounted higher and holds the capacitors in place. The 25K bleeder resistors mount on the capacitor terminals.

The high-voltage cable running to the amplifier is a length of RG-8/U terminated in a high-voltage coaxial plug (UG-59B/U). At the power supply end, the braid is peeled back for about a foot on the insulating material, to provide a suitably long leakage path. Disregard of this small point may result in voltage breakdown along the surface of the insulating material. The shield braid is connected to the base plate, which serves as the chassis ground. Wires to the a.c. line should be No. 14 or heavier (a cable marked "14-3 Type SJ 300 V" was used in this unit), and No. 16 wire will suffice for the control wiring.

If desired, a precision resistor can be used for R_3, the voltmeter multiplier. However, selected standard 20-percent resistors will serve as well.

Safety Precautions

A 3000-volt power supply with a 30-μf. filter capacitor is a lethal device. There is no such thing as a "slight electrical shock" from a power supply like this one. Make absolutely certain that the voltmeter indication has coasted down to zero before removing the protective cover or touching anything remotely connected to the high-voltage lead. Even then it is a good idea to use a "shorting stick" across the output as a double check.

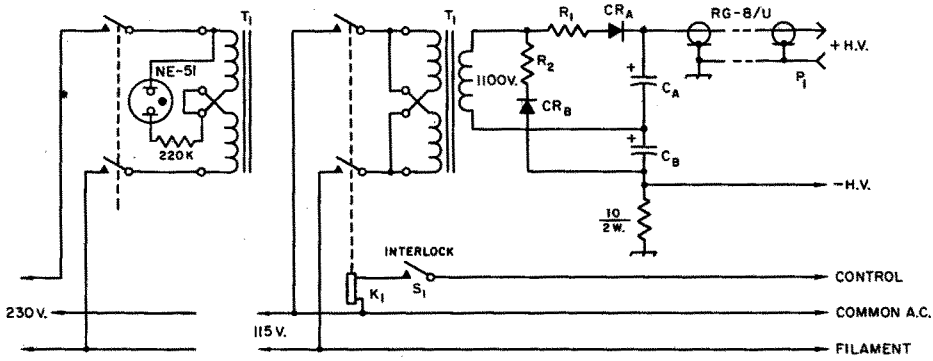
Adjustment of the Amplifier

An amplifier of this quality and power level deserves the best of treatment, and to that end it is recommended that the operator familiarize himself with its operation by using a dummy load, an oscilloscope and some method of "pulsing" the drive. This will enable the operator to work the amplifier at its maximum legal capacity with a minimum of spurious radiation.

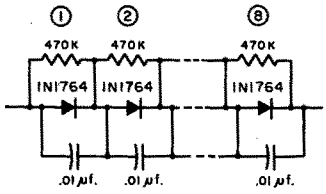
Lacking the equipment mentioned above, it is possible to approach proper operating conditions by the following rules of thumb. They are intended, however, to serve only as rough guides.

With a sideband exciter set for c.w. operation, feed its output to the amplifier at input jack J_1, through a length of RG-58/U or RG-8/U terminated in a PL-259 coaxial plug. If an s.w.r. indicator (for 50-ohm cable) is available, insert it in the line and switch it to read reflected power. With the filament of the amplifier turned on, but with the plate voltage turned off, tune the sideband exciter at low output level, using the grid-current indication in the grounded-grid amplifier as the output indicator. Peak L_1. It may be found that a little reflected power is indicated, but that is not important at this time. The exciter tuning and loading should approximate those obtained with any other 50-ohm load.

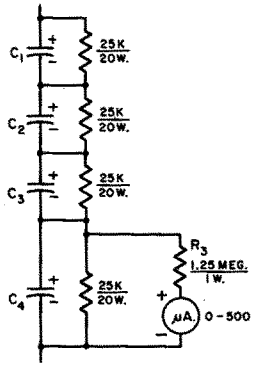
Plate voltage can now be applied, but it is recommended that early tests be carried out at half operating voltage, until it has been estab-



(A) SIMPLIFIED SCHEMATIC



(B) CR_A, CR_B DETAIL



(C) C_A, C_B DETAIL. VOLTMETER ON C_B ONLY.

Fig. 6-77—Schematic diagram of the 3000-volt power supply.

C_1–C_4—240μf. 450-volt electrolytic (Mallory CG241T450D1).
K_1—D.p.s.t. relay, 25-ampere contacts (Potter & Brumfield PR7AY, 115-v.a.c. coil).
P_1—Coaxial plug, UG-59B/U (Amphenol 82-804).
R_1, R_2—50-ohm 25-watt wirewound (Ohmite 0200D).
R_3—Selected 0.47- and 0.68-megohm, ½ watt, in series.
S_1—S.p.s.t. miniature switch (Acro BRD2-5L).
T_1—1100-v. 600 v.a. transformer, dual primary (BTC-6181, Berkshire Transformer Corp., Kent, Conn.)
25K, 20-watt resistors are Ohmite Brown Devil 1845, 470K resistors are ½-watt, 0.01-μf. capacitors are 1000-volt disk ceramic.

lished that it is possible to tune to the various bands. Never apply plate voltage to the amplifier without a load (dummy or antenna) being connected, because there is danger of burning out CR_1 under these circumstances. Having established that the circuits can be tuned, the amplifier can be tested at full voltage. The loading and excitation (single tone, same as steady carrier or c.w.) should be adjusted to give the readings shown below, with the understanding that these are only general guides and are not strict limits. Notice that these conditions represent tuning to a steady 1 kilowatt input, the only possible legal procedure (without pulsing, which is illegal except into a dummy load). When a set of these conditions has been met, adjust the output of the exciter to drive the amplifier just to an indicated 1 kilowatt plate input on peaks.

Plate Voltage	2500	3000
No-Signal Plate Current	160 ma.	180 ma.
Single-Tone Grid Current	100 ma.	75 ma.
Single-Tone Plate Current	400 ma.	330 ma.

As a final touch, adjust the input circuits for minimum reflected power.

Although the amplifier should have no v.h.f. parasitic with the suppressor as shown (RFC_2R_1 in Fig. 6-71), the amplifier should be tested for one. Disconnect the exciter, connect a dummy load to the output, switch to 21 or 28 Mc. and apply filament and then plate power. With one hand on the plate power supply switch, swing the plate capacitor, C_3, through its range, starting at maximum capacitance. If a parasitic is possible, it will probably show up as C_3 approaches minimum capacitance; it will be indicated by a sudden increase in plate current and the appearance of grid current. If a parasitic does appear, it will be necessary to increase the inductance of RFC_2 (after turning off the plate power!) by pushing the turns together or adding another turn.

USING 2 3-500ZS IN GROUNDED GRID

This linear amplifier operates in a grounded-grid circuit and uses two Eimac 3-500Z zero-bias triodes. It is capable of the maximum legal power input level, 1000 watts dc, and can develop up to 2000 watts peak input during ssb operation. The amplifier is intended for use on cw and ssb, and is not recommended for a-m service. The amplifier requires a driver that can deliver at least 65 wats PEP. Actually, it is best to use a driver that is capable of 100 watts PEP, to assure that sufficient driving power is available on 21 and 28 MHz, the frequencies at which the efficiency of coupling circuits is often poor in comparison to that of the lower bands.

In the circuit of Fig. 6-66, a pi-network input circuit (C_1, C_2, and L_1) is used to aid linearity and to lessen the driving power requirements. Only one tuned circuit is shown in the diagram for reasons of clarity. The remaining tuned circuits (described in the coil table) are connected to the rest of the contacts shown for S_1. Relay K_1 routes the input (J_1) around the amplifier to J_2, thus enabling the operator to keep the amplifier in standby while transmitting around it with his exciter or transceiver when low-power operation desired. Also, this switching arrangement connects the antenna to the transceiver during receive periods, bypassing the amplifier. The changeover relay, K_1, and the bias control relay, K_2, are controlled by external means; J_4 connects to the VOX or push-to-talk circuit of the driver. The input tuned circuit is connected to the filament rf choke, a bifilar-wound inductor consisting of 28 turns (double) of No. 10 Formvar-insulated wire. The turns are close-wound on a ½-inch diameter ferrite rod, 7½ inches long.

A homemade tank coil is used in the plate circuit of the amplifier. Capacitor C_3 is a 300-pF Jennings vacuum variable, and provides the proper capacitance for all of the bands.

An rf sampling circuit is connected to the output of the amplifier (CR_2). Rectified rf is fed to M_3 through the sensitivity control, R_1, for tuning adjustments. There is no reason why this circuit could not be replaced by an SWR bridge so that reflected-power readings could be used for Transmatch adjustments.

Bias resistor R_2 is used to cut the amplifier off during standby periods. During transmit it is shorted out by the contacts on K_2. Forced-air cooling is provided by B_1, a 100-c.f.m. blower. S_4 turns on the filaments supply and blower fan. S_3 turns on the relay supply and activates the plate power supply control relay.

Construction Notes

This equipment is built on a standard 13 × 17 × 4-inch aluminum chassis. The panel and cabinet are home made. A standard rack panel can be used, if desired. The assembly is enclosed in a cover made of sections of aluminum sheeting and perforated aluminum material (Reynolds).

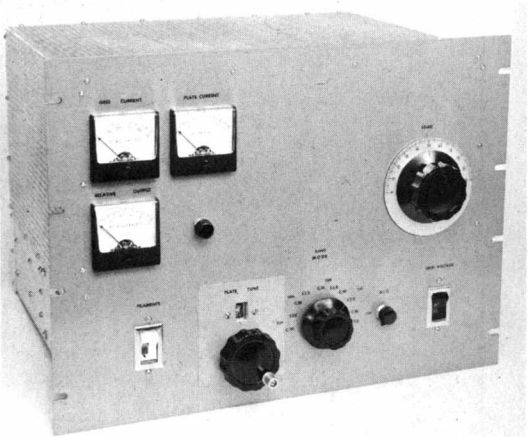


Fig. 6-65—Front view of the amplifier using two 3-500Zs. The grid-current meter is at the center left, with the plate meter to the right and the rf-output meter below. The entire assembly is well shielded to lessen the chances for TVI. The dial counter used on the vacuum-variable capacitor is from a surplus BC-610 antenna tuner. (*Built by Carl E. Smith, W1ETU*)

This was done for TVI reasons, and to prevent accidental contact with rf and dc voltages within. The bottom of the assembly is enclosed by means of an aluminum plate. Forced-air cooling is effected by mounting B_1, the blower, on the rear deck of the chassis, under the Eimac SK-410 tube sockets. The corners of the chassis are plugged with epoxy cement to prevent air from escaping through paths other than the intended one. Each tube has an Eimac SK-406 chimney, assuring that the air stream is directed along the sides of the tubes. Heat-dissipating plate caps are used as anode connectors.

All non-signal leads, except the high-voltage bus, are bypassed where they enter the chassis in the interest of TVI prevention. In actual service, the panel meters are enclosed in a shielded compartment.

To obtain the maximum power output, the LC ratio of the tank circuit must be optimum for the voltage and current used. One feature of this amplifier is that a separate tank tap is provided for 1- or 2-kW operation on each band. Operators planning only cw or ssb service can leave out the taps for the unwanted mode.

When winding RFC_1 it is suggested that a piece of 7/16-inch diameter wooden dowel be used as a form. After the coil has been wound, slip it off the dowel and mount it on the ferrite rod. Because of the stress needed when winding the No. 10 wire, the ferrite might break if used as a former.

Adjustment and Performance

Although any voltage between 2000 and 3000 can be used with this amplifier, the latter is recommended for best efficiency with this circuit;

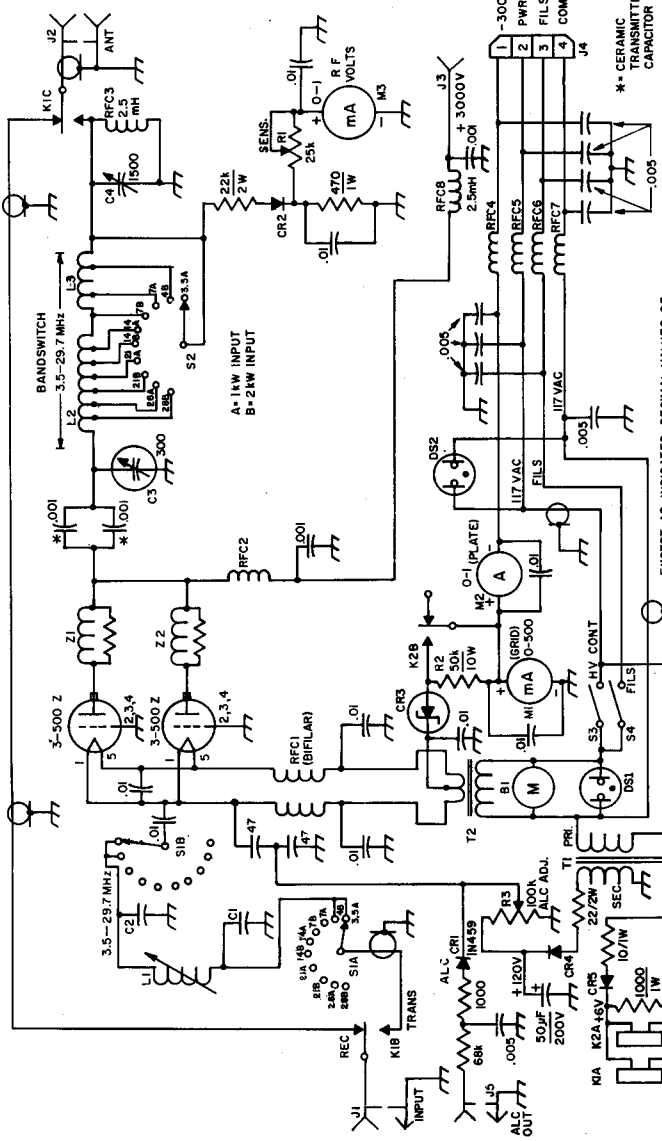


Fig. 6-66—Schematic diagram of the 2-kW amplifier. Fixed value capacitors are 1000-volt disk ceramic unless otherwise indicated. Capacitors with polarity marked are electrolytic.

B_1—115-V ac, 100-cfm blower (Burstein-Applebee 41A4003).
C_1, C_2—See table.
C_3—Vacuum variable, 300 pF (Jennings-ITT).
C_4—1500-pF transmitting variable (104-12 from LaPointe Industries, Rockville, CN06066).
CR_1—High-frequency type (1N458 or 1N459).
CR_2—Germanium (1N34A or 1N67).
CR_3—Zener, 6.8 V, 50 W (International Rectifier Z3305-C).
CR_4—600-PRV, 1-A silicon.
CR_5—100-PRV, 1-A silicon.
DS_1, DS_2—Part of S_3 and S_4.
J_1, J_5, J_6—Phono jack, panel mount.
J_2—SO-239-style chassis connector.
J_3—Millen 37001 high-voltage chassis-mount connector.
J_4—Male 4-pin chassis-mount connector (Cinch-Jones P-304-AB).
K_1—Dpdt 6-volt dc relay (Potter & Brumfield KT-11D).
K_2—Spdt 6-volt dc relay, one contact not used (Potter & Brumfield KM5D).
L_1—See coil table.
L_2—11½ turns of ¼-inch copper tubing, 2¼-inches inside diameter, approx. ⅛-inch spacing between turns. Tap at 1¼ turns in from the amplifier tube end for 28B, 3¼ turns for 28A, 3½ turns for 21B, 5½ turns for 21A, 5¾ turns for 14B, 8½ turns for 14A, and full coil for 7B.
L_3—15 turns, No. 12 wire, 6 tpi, 2½-inch diameter, tapped at 6 turns in from the junction with L_1 for 7A, 8 turns for 4B, and full coil used for 3.5A (Polycoil type 1774).
M_1—0 to 500-mA dc meter (Simpson type 06290).
M_2—0 to 1-A dc meter (Simpson type 02440).
M_3—0 to 1-mA dc meter (Simpson type 06175).
R_1—25,000-ohm, linear-taper carbon control.
R_2—See text.
R_3—100,000-ohm, linear-taper carbon control.
RFC_1—Bifilar filament choke wound on ½-inch dia. ferrite rod (Newark Electronics 59F1521), see text for winding details.
RFC_2—Transmitting-tube rf choke (National Radio R-175A or B&W 800).
RFC_3—2.5-mH, 150-mA rf choke.
RFC_4-RFC_8, incl.—22 turns, No. 14 enam. wire, ½-inch dia.
S_1—Ceramic rotary switch, 2-pole, 17 position (10 used), 2 section, non-shorting contacts (Centralab PA-3003).
S_2—Ceramic rotary power switch, 1 pole, 17 position (10 used), 1 section, non-shorting contacts (Centralab JV-9001).
S_3, S_4—Spst lighted rocker switch (Carling LT1LA65).
T_1—125-V, 15-mA and 6.3-V, 0.6-A power transformer (Stancor PS-8415).
T_2—5-V, 30-A filament transformer (Stancor P-6468).
Z_1, Z_2—Homemade parasitic choke consisting of 2 turns of ⅜-inch flat copper or brass strap around a Workman FRT-1 thermistor.

L_1 COIL TABLE

Band	C_1, C_2	L_1
80	1600 pF (Arco VCM-35B162K)	16 t., closewound
40	910 pF (Arco VCM-20B911K)	8 t., closewound
20	430 pF (Arco VCM-20B431K)	6 t., closewound
15	300 pF (Arco VCM-20B301K)	4 t., closewound
10	220 pF (Arco VCM-20B221K)	4 t., spaced to fill form.

Capacitors are 1000-V silver mica. Inductors wound with No. 16 Formvar or Nylclad on ½-inch diam. slug-tuned form (No. 69046—James Millen Co., 150 Exchange St., Malden, Mass.)

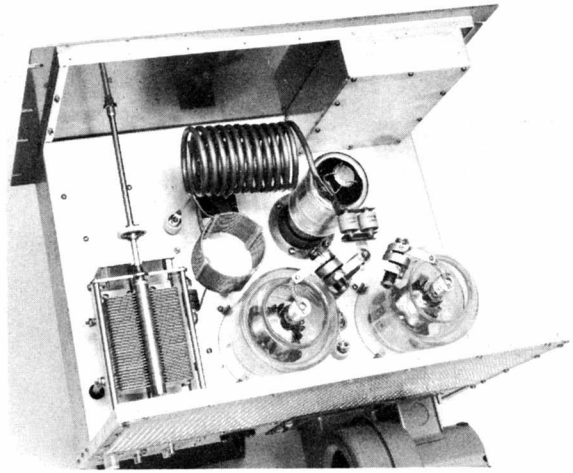


Fig. 6-67—Looking into the top of the amplifier, the vacuum variable is mounted at the center, in front of the two 3-500Zs. The loading capacitor is at the far-left side of the chassis. Hidden behind the homemade tank coil is the plate band switch. Eimac sockets and chimneys are used with the tubes, and air is forced into the pressurized chassis by the 100-cfm blower on the rear deck. A box encloses the panel meters (on the right-hand side of the front panel). Full shielding of the meters is required to prevent stray radiation that could cause TVI.

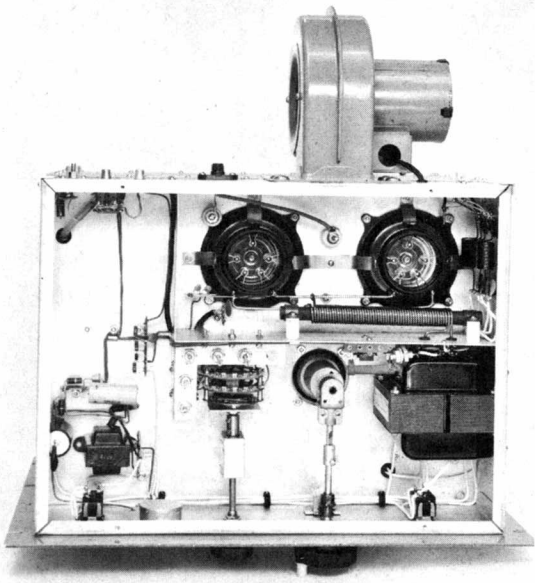


Fig. 6-68—On the under side of the chassis, the filament transformer is at the lower right. The filament choke is inside the shielded partition that closes off the tube-socket compartment. A right-angle drive, Millen 10012, drives S_1 and S_2 (it is visible at the center-front portion of the chassis). The power supply for the relays and alc system is at the front-left side. The blower is mounted on the rear deck, with a piece of foam insulation between the blower housing and the chassis to reduce vibration and noise. A full bottom cover is required.

the L-C ratio in the plate tank is designed for 3000-volt, one- or two-kW input operation. One must always be mindful that *lethal voltage* is being used here. *Never apply the high voltage while the top or bottom covers are removed.* Do not handle the power supply until it is turned off and unplugged from the ac outlet. Allow plenty of time for the filter capacitors to bleed off, using a shorting stick to discharge them as a final safety measure.

Resting plate current (no signal) for this amplifier will be approximately 150 mA with R_2 shorted out. As much as 200 mA of grid current can flow during peak drive periods. In practice, with 3000 volts on the plates, approximately 150 mA of grid current was noted when the full legal power input was being run.

With the amplifier's covers in place, a dummy load connected to the output, and an SWR indicator connected between the driver and the input jack, J_1, apply a small amount of drive (single-tone or cw) and adjust L_1 for minimum SWR. Adjust C_3 and C_5 for maximum output as noted on M_3. Gradually increase the drive until the loaded plate current, at dip, is 330 mA. This will provide 990 watts dc input to the tubes; the output will be approximately 650 watts. For 2-kW PEP input, connect the amplifier to a dummy load and adjust the cw or pulsed-tone drive for 667 mA plate current (3000 volts). Adjusting for 2-kW dc input in this manner should not be done with the antenna connected, in order to comply with FCC regulations. *Stay legal!*

Spectrum-analyzer tests show this amplifier to have an IMD level (intermodulation distortion) that is down in excess of 30 dB at 2-kW peak input. Harmonic output was down some 40 dB from the fundamental.

The power supply for this amplifier is described in Chapter 12, and in December 1969 *QST*.

THE SS-2000 AMPLIFIER

The SS-2000 linear amplifier is designed to handle the legal maximum power input on cw and ssb. Because of the high plate-dissipation rating of the tube there is plenty of safety margin to prevent tube damage in the event of accidental mistuning. This amplifier is carefully shielded and filtered for the reduction of TVI. Though a 3-1000Z tube is used, the popular 4-1000A can be substituted as mentioned later. Both tubes have a maximum plate dissipation of

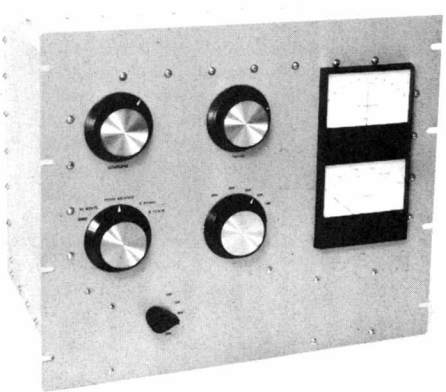


Fig. 6-69—The front panel of the 2-kW PEP amplifier has the controls grouped at the left. The panel has been sprayed with gray enamel, and black decals identify the controls. The hardware visible in this photograph secures the TVI shielding.

A SWEEP-TUBE LINEAR AMPLIFIER

Fig. 1 — Front view of the 800-watt amplifier. An LMB CO-1 cabinet, Simpson 02640 meter, and Kirsh-Kash S-649-70L knobs are used, giving a modern appearance. Coils are changed through the door in the top of the cabinet.

This simple 800-watt PEP sweep-tube amplifier is designed for use on the 160-, 80-, 40-, and 20-meter bands. It is a self-contained unit, complete with power supply and antenna relay. *Note that in some areas of the country this amplifier cannot be used at full input power on the 160-meter band.* The amplifier is designed to be a low-cost companion to any of the single- and triband hf transceivers. (A 160-meter transverter is described in Chapter 13.) Because only low-duty-cycle transmission is suitable for sweep tubes operated at high power levels, this amplifier cannot be used for a-m, fm or RTTY service.

Circuit Data

Four 6KD6 color-TV sweep tubes are used in parallel in the circuit of Fig. 2. This grounded-grid amplifier operates in the Class-AB region.

The extremely low plate-load impedance of this amplifier – approximately 500 ohms – requires that special measures be taken to match the plate circuit to the load. A tapped-coil arrangement at L1 aids in obtaining a suitable match. Individual 10-ohm resistors are used in each cathode lead to aid in balancing the tubes for equal resting plate currents. Bias is developed across Zener diode VR1.

K1 provides a "switch-through" feature which permits the antenna to be used during receive. Also, by not activating K1 the transceiver can be used (bypassing the amplifier) while the amplifier is kept ready for use. If the operator does not plan to use this amplifier with a transceiver, the relay contacts can be rewired for antenna changeover – the usual arrangement for separate transmitter and receiver setups.

Construction

The general layout can be seen in the photographs. The equipment is built in an LMB CO-1 cabinet. Any homemade or commercially built cabinet of suitable size (more than 14 X 12 X 6-inch) may be employed.

Inductors RFC1, RFC2 and RFC3 are hand-wound. RFC3, the plate rf choke, is wound for operation at low impedance over the range from 3.5 to 30 MHz. It was designed with the aid of an RX meter and "looks" like 100,000 ohms on all bands but 10 meters. On ten meters it looks like 25,000 ohms. RFC1 and RFC2 consist of 65 turns of enameled wire on lengths of 1/2-inch diameter ferrite rod. Homemade brass anchors, 1/8-inch wide, are snapped onto each end of each rod and are used as tie points for the ends of the windings. RFC1 and RFC2 are attached to chassis standoff posts by means of plastic cable clamps. L1 is mounted by means of bus-wire pigtails. RFC3 is wound on a piece of 3/4-inch diameter polystyrene rod. A steatite rod can also be used. (An H. H. Smith 2630 standoff would be suitable, and it has a threaded hole at each end for attaching terminals.)

L2 and L3 are made up as plug-in assemblies so that the amplifier can be used as a single-band unit. Band-switching arrangements would not be practical with the type of tank circuit used. A pi-network tank could be used, and switched, but because of the very low impedance of the plate circuit, the amount of capacitance required for the input and output capacitors of the pi-section tank would be impractical if a satisfactory Q were to result on 160, 80 and 40 meters. The plug-in coils are mounted on James Millen 41305 jack-bar plugs.

C1 is a 160-pF transmitting-type variable taken from a surplus TU tuning unit. Any variable capacitor with similar capacitance and plate spacing (approximately 1/8 inch) can be substituted.

A high-speed cooling fan is used to keep the tube envelopes at a safe temperature. The forced-air cooling also helps to prevent damage to the plates of the tubes from excessive heating. The fan blades should be mounted close to the tubes and should be capable of providing 100 ft^3/m or better.

Power Supply

The primary side of T1 has a neon indicator across the line, DS2, to serve as an on-off panel indicator. K2 and the 25-ohm resistor are used when the supply is first turned on (S2 open) to provide protection to CR1 through CR8, inclusive, while the filter capacitor bank charges. The relay will remain open for a few seconds, gradually closing and shorting as the capacitors become charged. U1, a G.E. Thyrector assembly, is bridged across the primary of T1 to knock down any transients above the normal primary level, thus offering protection to the diode string in the secondary circuit.

Eight diodes are used in a full-wave rectifier circuit at the secondary of T1. Each diode has a

The SS-2000 Amplifier

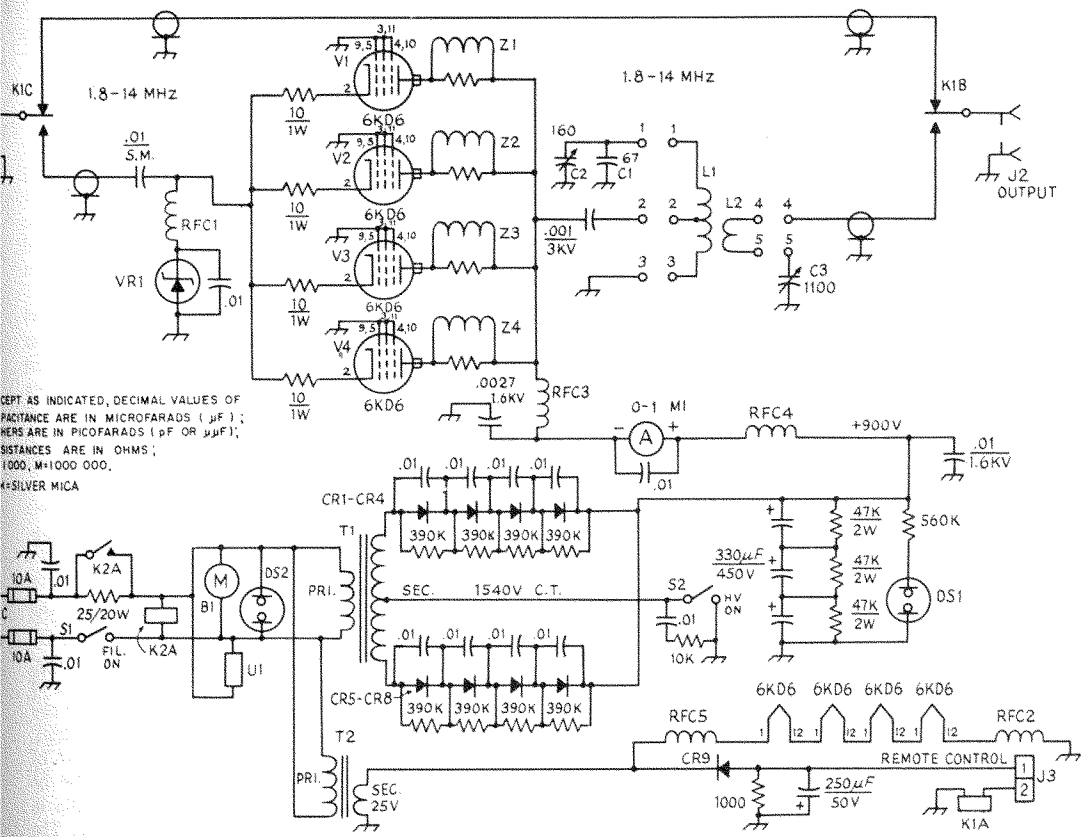


Fig. 2 — Schematic diagram of the linear amplifier. Fixed-value capacitors are disk ceramic unless otherwise indicated. Resistors are 1/2-watt composition uless otherwise marked.

B1 — High-speed fan (Barber-Coleman DYAF 761-110 with AYFA-403 blades suitable).

C1 — 67-pF, 2000-V mica or ceramic transmitting type.

C2 — Transmitting variable, 1/8-inch plate spacing (see text).

C3 — 3-section broadcast variable, 365-pF per section; all sections connected in parallel (J. W. Miller 2113 or equiv.).

CR1-CR9, incl. — Silicon diode, 1000 PRV, 1 A.

DS1, DS2 — Part of S1 and S2, respectively.

J1, J2 — SO-239-type chassis connector.

J3 — 2-circuit terminal strip.

K1 — 24-volt dc relay with 10-A contacts.

K2 — 117-volt ac relay with 20-A contacts (double-pole unit with parallel-connected contacts suitable).

L1 — 160 meters — 40 turns, No. 14, 2 1/2-inch dia, tap at 12 turns (B&W 3029). 80 meters — 18 turns No. 12 wire, 2 1/2-inch dia, 3 inches long, made from Polycoils 1774 stock. Tap 6 turns down from C1 end. 40 meters — 12 turns No. 12 wire, 2 1/2 inch dia, 3 inches long, made from Polycoil stock. Tap 3 down from C1 end. 20 meters — 8 turns No. 10 wire, 1 1/4-inch ID, 3 inches long. Tap 3 turns from C1 end.

L2 — 160 meters — 11 turns No. 12, 3-inch dia, over the ground end of L1 (Polycoil 1779). 80 meters — 5 turns No. 14 wire, 3-inch dia, approx. 3/4 inch long. Mount over outside of L2 at ground end. 40 meters — 3 turns No. 14 wire, 3-inch dia. Mount over ground end of L2. 20 meters — 2 turns No. 12 wire, 2 inches dia. Mount over ground end of L2.

M1 — 0 to 1-ampere dc meter (Simpson 1227 used).

RFC1 — 65 turns No. 20 enam. wire, close-wound on a 4-inch length of 1/2-inch dia ferrite rod, approx. 200 μH.

RFC2, RFC5 — 55 turns on Amidon T-130-2 toroid core. Core wrapped with 3M No. 27 glass tape. Both windings on one core, using No. 16 enam. wire.

RFC3 — See text and Fig. 4.

RFC4 — 2.5 mH rf choke.

S1, S2 — Rocker switch with built-in neon indicator.

T1 — 1540 V ct at 375 mA (Stancor P-8042 suitable. Available from Arrow Electronics, Inc., 900 Route 110, Farmingdale, NY, 11735).

T2 — 25.2-V filament transformer (Stancor P-8388).

U1 — Thyrector transient suppressor (G.E. 20SP4B4).

VR1 — 6.9-V, 50 watt Zener diode.

Z1-Z4, incl. — Parasitic choke. 8 turns No. 24 enam. wound on body of 56-ohm 1-watt carbon resistor. Use resistor pigtails as solder terminals for ends of windings. Mount near plate caps.

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[1] The pilot lamps and the three rocket switches used here are available from Carling Electric, Inc., 505 New Park Avenue, West Hartford, CT 06110. Order direct if not locally available. Catalog available if requested.

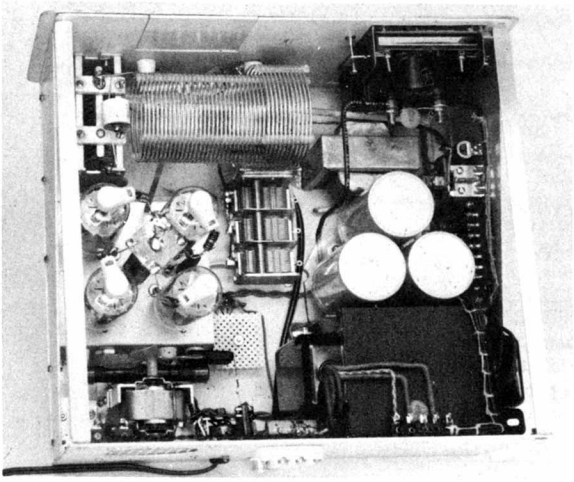
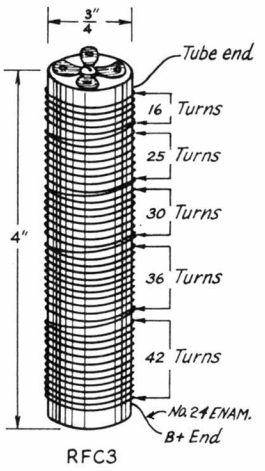


Fig. 3 — The power supply is constructed along the left-hand side. A flat sheet of aluminum is used as a base. The four sweep tubes are mounted on a small 4 X 4 X 1 1/4-inch U-shaped bracket at the upper right. The meter is mounted behind the panel using a Simpson 01253 bezel mounting kit.



RFC3

Fig. 4 — Details for winding the plate choke, RFC3.

resistor and a capacitor across it to offer protection in the event the voltage division across the diodes is unequal. S2 is the HV ON switch and has a transient suppressor across it to prevent damage to the switch when it is cycled.

Three computer-grade capacitors are series-connected at the output of the rectifier to provide 110-μF at 1350 volts. Each capacitor has a 47,000-ohm resistor across it to assure equal voltage drop. DS2 is the high-voltage ON indicator. Output from T2 is for the filament supply.

Operation

Approximately 50 watts of peak driving power are required to operate this amplifier at its rated 800 watts (PEP) input. If the transceiver being used as a driver has more power output than 50 watts, merely turn the transceiver's audio-gain control down until the power output is correct.

With a 50-ohm dummy load attached to J2, and with operating voltages applied, apply a small amount of drive until an increase in plate current is evident (approximately 100 mA). Adjust C2 until a dip in plate current occurs. Increase drive until 300 mA of plate current is indicated on M1. Quickly dip the plate current and remove drive. Warning: *Do not allow continuous plate current in excess of 100 mA to flow for more than 30 seconds at one time.* Allow 30 seconds for cooling between tests. Next, apply drive until approximately 800 mA of plate current is obtained at dip. C3 should be adjusted for proper loading, making the dip in plate current somewhat broad and shallow. The amplifier is now ready for use and will have a dc input of 800 watts at this setting. Tests made with a spectrum analyzer showed that the IMD (intermodulation distortion) was very good at this power level. The third-order products were down some 27 decibels, and the fifth-order products were down in excess of 50 dB. The second harmonic product was measured at 35 dB down. If the operator does not mind the risk of shortened tube life, the power level can be 1000 watts PEP input. The efficiency of the amplifier is approximately 65 percent.

Other types of tubes can be substituted in this circuit, but few will permit the power level discussed in this amplifier. A good substitute might be the 6LQ6.

THE SS-2000 AMPLIFIER

The SS-2000 linear amplifier is designed to handle the legal maximum power input on cw and ssb. Because of the high plate-dissipation rating of the tube there is plenty of safety margin to prevent tube damage in the event of accidental mistuning. This amplifier is carefully shielded and filtered for the reduction of TVI. Though a 3-1000Z tube is used, the popular 4-1000A can be substituted as mentioned later. Both tubes have a maximum plate dissipation of 1000 watts. A suitable power supply for this amplifier (3000 volts) is described in the chapter on power supplies.

Circuit Description

Referring to Fig. 2, the amplifier is connected for grounded-grid operation. Excitation is applied through a switchable pi-section input tuned circuit. This network serves a twofold purpose: It reduces the amount of drive needed, by virtue of proper impedance matching between the exciter and the amplifier. It improves the IMD of the amplifier by providing the exciter with a better load than might otherwise exist. Approximately 50 watts of drive will be ample for the 3-1000Z. Roughly 125 watts

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of excitation will be needed if a 4-1000A is used in this circuit.

A pi-network plate tank is used in the output side of the amplifier. It uses homemade coils wound with 1/4-inch diameter copper tubing. The L-C ratio was chosen for operation at 3000 volts. Lower plate voltages will permit power in excess of 1 kW, but a different set of coil taps will be required if a suitable Q is to be maintained. The lower plate voltages will necessitate the use of more C and less L in the tank.

A tuning/loading-indicating circuit is connected between the grid and plate terminals of the tube. It samples the input and output waveforms, rectifies them, and compares their different voltage by means of a zero-center microampere meter, M2. If the amplifier is mistuned, or is looking into an improper load, the meter will deflect off zero and indicate a nonlinear condition. Those not wishing to use the linearity detector may omit it from the circuit. Additional metering is provided for by M2 – plate voltage, grid current, and forward and reflected power. The SWR metering is made possible by the bridge shown at the upper right of Fig. 2. It is patterned after a design in the Measurements chapter, and can be made to serve as a zero to 2000-wattmeter by selecting the proper-value resistors at R3 and R4. By substituting 25,000-ohm potentiometers for the fixed-value calibrating resistors, the job should be a bit less tedious. A power calibration scale can be plotted for M2 by checking power output with an rf ammeter, or by comparing meter readings with a commercial wattmeter. T2 is a toroidal transformer consisting of 60 turns of No. 30 enameled wire, close-wound on an Amidon T-68-2 form. The bridge is built in a Minibox and is mounted on the rear-outer wall of the amplifier case. A zero to 1-ampere panel meter, M1, monitors the plate current of the 3-1000Z.

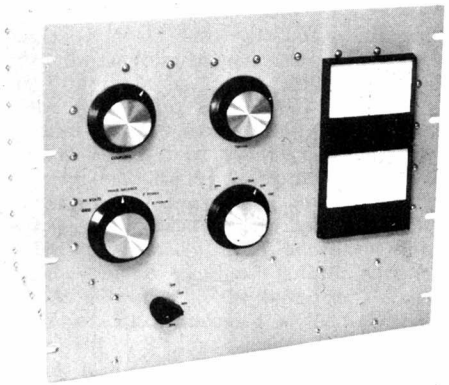

Fig. 1 – The front panel of the 2-kW PEP amplifier has the controls grouped at the left. The panel has been sprayed with gray enamel, and black decals identify the controls. The hardware visible in this photograph secures the TVI shielding.

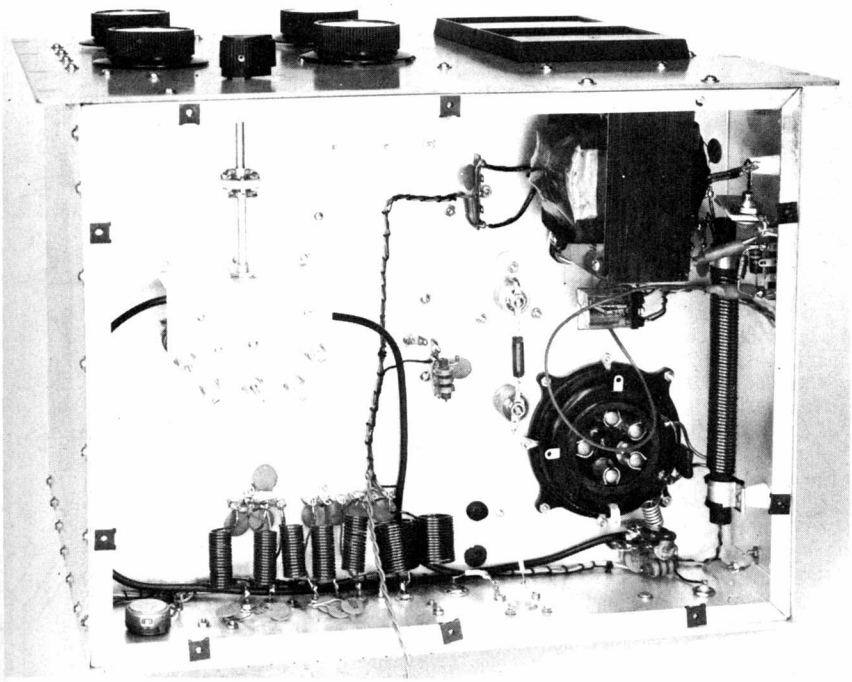

Fig. 2 – In this bottom view of the amplifier, the filament transformer is visible at the upper right, just above the filament choke which runs along the right wall of the chassis. Relay K1 is located between the transformer and the tube socket. The slug-tuned coils of the cathode network are at the left, with the pi-section filters for the power leads just below. A ceramic feedthrough bushing is used to carry the 3000-volt lead up through the chassis.

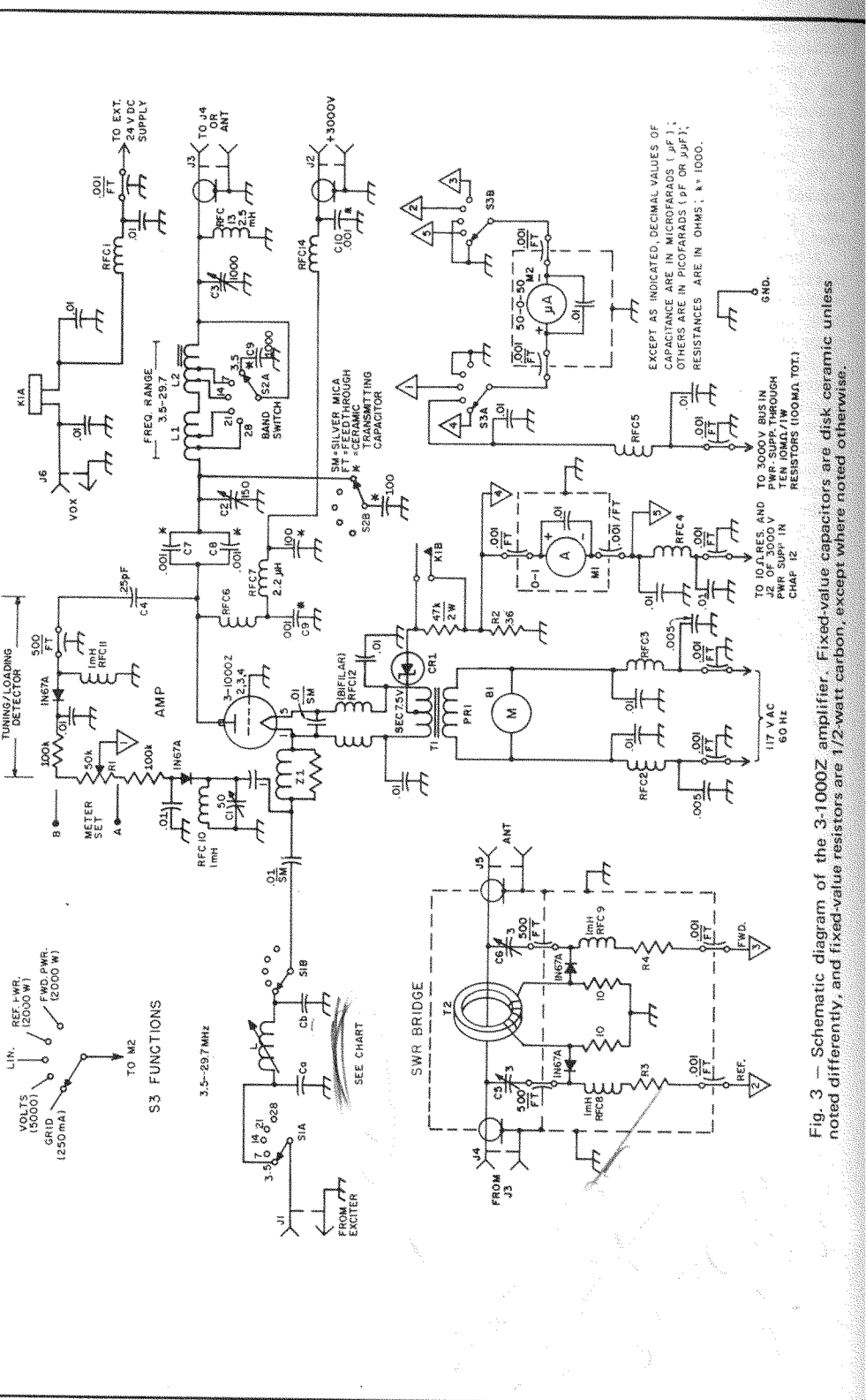
S3 FUNCTIONS
VOLTS (5000) GRID (250 mA)
LIN.
REF. PWR. (2000 W)
FWD. PWR. (2000 W)
TO M2
3.5–29.7 MHz
SEE CHART
FROM EXCITER
SWR BRIDGE
FROM J3
TO J4 OR ANT
TO EXT. 24 V DC SUPPLY
+3000V
VOX
TUNING/LOADING DETECTOR
METER SET
AMP
3-1000Z
FREQ. RANGE 3.5–29.7
BAND SWITCH
SM=SILVER MICA
FT=FEED THROUGH CERAMIC
TRANSMITTING CAPACITOR
117 V AC 60 Hz
TO 10 Ω RES. AND J2 OF 3000 V PWR SUPP IN CHAP 12
TO 3000 V BUS IN PWR. SUPP. THROUGH TEN 10MΩ/1W RESISTORS (100MΩ TOT.)
GND.
EXCEPT AS INDICATED, DECIMAL VALUES OF CAPACITANCE ARE IN MICROFARADS (μF); OTHERS ARE IN PICOFARADS (pF OR μμF); RESISTANCES ARE IN OHMS; k = 1000.

Fig. 3 — Schematic diagram of the 3-1000Z amplifier. Fixed-value capacitors are disk ceramic unless noted differently, and fixed-value resistors are 1/2-watt carbon, except where noted otherwise.

B1 — 117-V ac, 100-ft³/m blower (Burstein-Applebee 41A4003).
Ca, Cb — See table.
C1 — Trimmer, 50 pF (Centralab 822AN).
C2 — Transmitting air variable, 150 pF (Johnson 154-15).
C3 — Transmitting air variable, 1000 pF (Johnson 154-30).
C4 — See text.
C5, C6 — Piston trimmer, 0.5 to 3 pF (JFD 25G).
C7-C10, incl. — Transmitting type (Centralab 858S-1000).
CR1 — Zener, 6.8V, 50 W (International Rectifier 23305-C).
J1, J6 — Phono jack, panel mount.
J2 — HV coaxial connector, chassis mount, type HN.
J3, J4, J5 — SO-239-style chassis-mount connector.
K1 — Spst 24-volt dc relay.
L — See table.
L1 — 11 turns, 1/4-inch dia copper tubing, 1 1/2-inches ID, space turns so that the entire coil is 3 1/4 inches long. Tap at 5 turns for 28 MHz and 9 turns for 21 MHz.
L2 — 10 turns, 1/4-inch dia copper tubing, 3 1/2 inches ID, space turns so that the entire coil is 4 inches long. Tap at 2 turns for 14 MHz, 7 turns for 7 MHz, and use the entire coil for 3.5 MHz. Inside the 3.5-MHz end of the coil is a package of eight 2-inch long, 1/2-inch dia ferrite rods (cut from the stock specified for RFC12).
M1 — 0 to 1-A meter (Simpson 17565).
M2 — 50-0-50-μA meter (Simpson 17597).
R1 — 50,000-ohm linear-taper composition control.
R2 — 0.36 ohms, 25 turns of No. 30 enam. wire on the body of a 1/2-watt composition resistor.
R3, R4 — Selected to give full-scale deflection (forward power) on M2 at 2000 watts. (See text for details.)
RFC1, RFC4, RFC5 — Rf choke, 18 turns No. 14 enam. wire, close-wound, 1/2-inch dia.
RFC2, RFC3, RFC14 — Rf choke, 24 turns No. 14 enam. wire, close-wound, 1/2-inch dia.
RFC6 — Rf choke (National Radio R-175A or B&W 800).
RFC7 — 2.2-μH rf choke (Miller 74F226AP or equiv.).
RFC8, RFC9 — 1-mH rf choke (Millen J300-1000).
RFC10, RFC11 — 1-mH rf choke (Miller 4652).
RFC12 — Bifilar filament choke, 28 turns of No. 10 enam. wire, close-wound on 1/2 X 7 1/2-inch ferrite rod (Newark Electronics 59F1521 ferrite rod suitable).
RFC13 — 2.5-mH rf choke (National R-100 or equiv.).
S1 — Ceramic rotary switch, 2-section, 6 position (5 used), 2 pole, non-shorting contacts (Centralab 2511).
S2 — Ceramic rotary power switch, 2 pole, 1 section, 8 position (5 used), non-shorting contacts (Centralab JV-9033).
T1 — Filament transformer, 7.5 volts, 21 A (Triad F28U).
T2 — Toroidal transformer (see text).
Z1 — Rf choke, 6 turns No. 16 on the body of a 100-ohm, 1-watt composition resistor.

Construction Notes

The SS-2000 is built on a 13 X 17 X 4-inch chassis (Bud AC-428), and uses surface-shield panels for the front and rear walls of the enclosure. The front panel is 15 3/4 inches high, and 19 inches wide (Bud SFA-1839). The rear panel measures 14 X 19 inches (Bud SFA-1838). If a 4-1000A tube is to be used it is recommended that the next size larger panels be used to allow clearance inside the cabinet for the tube. (The 4-1000A is somewhat taller than the 3-1000Z.)

The input tuned circuit is housed on a bracket near the center of the chassis bottom. Between this cathode network and the tube itself, a parasitic suppressor, Z1, is included to kill any tendency toward vhf oscillation. Locating this choke in the cathode lead eliminates the losses common in 21- and 28-MHz operation when parasitic suppressor is placed in the plate lead.

An Eimac SK-510 tube socket, and an Eimac SK-506 chimney are used in this amplifier. Grid grounding is effectively done by passing the leads through the slots in the side of the tube socket which were provided for this purpose. Grid-pin connections are made to long solder lugs which are bolted to the chassis at the tube socket. Short leads of heavy-guage wire or copper strips are vital to good amplifier stability.

Layout of the major components can be seen in the photos. It is important that a good ground connection be made between C2, C3, and the panel. Similarly, the panels should be securely grounded to the chassis. A heat-dissipating anode connector is used as an aid to tube cooling.

A 100-ft³/m blower is mounted on the bottom cover of the amplifier, slightly off center from the tube base. Its final positioning should be set for best air flow through the tube socket.

The terminal connections provided on T1 are much too bulky to be easily handled. They were replaced by smaller lugs that will accept No. 10 screws which thread into the ceramic pillars that are used as standoff insulators for the filament tie points.

The SWR bridge is housed in a 4 X 2 1/4 X 2 1/4-inch Minibox. Lead lengths should be kept short and as symmetrical as possible to assure proper operation. Good electrical balance is essential if the unit is to be balanced properly, thus assuring that it is truly bilateral. The dashed lines indicate shield compartments, Fig. 2.

Capacitor C4 in the linearity-detector circuit must be able to withstand high voltage and must be very low in capacitance value – on the order of 0.25 pF. In this model a glass piston trimmer is used for C4. The piston is removed and discarded. Connections for C4 are made by soldering to the foil wrap, top and bottom, with a low-heat soldering iron. An air-dielectric homemade capacitor could be fashioned from two copper tabs spaced 1/2 inch or more apart, firmly mounted on ceramic pillars.

Amplifier Adjustment

Initial testing should be carried out with a 50-ohm dummy load connected to the output of

the amplifier. If a Variac is available, gradually increase the high voltage to make certain that no short circuits or wiring errors are present, then increase the B plus to 3000 volts. At this point there should be no grid-current reading, but the resting plate current should be roughly 110 mA. Next, apply a small amount of driving power and observe the SWR meter. Tune the plate tank for maximum forward power, thus indicating resonance. Now, increase single-tone or cw drive until the resonant plate current is 330 mA. The grid current will now be approximately 75 mA. Operating in this manner the amplifier is adjusted for 1-kW dc input. Peak plate current for 2-kW ssb conditions will be 667 mA, and the grid current will be approximately 220 mA. All amplifier adjustments for arriving at the 2-kW PEP dc-input level must be made while using a dummy load if pulsed-tone or steady-carrier drive is applied to the amplifier. *Stay legal by not exceeding the legal 1 kW maximum dc input level when the antenna is connected.*

When adjusting the linearity detector the bottom cover of the amplifier is removed (*beware of high voltage*) and the amplifier is operated at an intermediate power level. With a voltmeter, check between point B and ground. The voltage, typically, will be between 0.5 and 1.5 volts. The voltage is then checked at point A, and C1 is adjusted to give the same voltage as is present at B. R1 is then set (amplifier operating at 2-kW into a dummy load) to give a reading of zero on M2. The meter reading is maintained at zero, thereafter, when the amplifier is properly adjusted and operating into a 50-ohm antenna.

In adjusting the SWR bridge, connect a dummy load to J5 and apply drive from the exciter to J4. Set M2 to read reflected power and place a shorting wire across R3. Adjust C6 for minimum meter deflection. Now, reverse the connections to J4 and J5, remove the short from R3 and place it across R4. Adjust C5 for minimum meter reading. Check for minimum reflected power at 28 and 3.5 MHz. It should be the same if the bridge is properly nulled. The values of R3 and R4 will have to be selected to give best accuracy at the 2000-watt input level. If an accurate wattmeter is available it can be used for calibrating the bridge. Small "trim pots" could be substituted for the fixed-value resistors to make adjustment easier. Their maximum resistance should be 50,000 ohms.

A ONE-KILOWATT AMPLIFIER USING A 3-500Z

Circuit design for high-power linear amplifiers hasn't changed much in recent years. The differences between various types of grounded-grid units are usually more mechanical than electrical. The degree of circuit complexity is determined primarily by the number of features desired and if the power supply and control circuits are included on the same chassis as the amplifier. Described below is a power amplifier designed to operate break-in cw as the primary mode. A suitable exciter is described earlier in the chapter. Other equipment combinations were shown in *QST* for December 1971.

The Power Supply

A voltage-doubler circuit connected to the secondary of T1 provides approximately 2600 volts dc. See Fig. 1. The primary of T1 can be operated from either a 117-volt line or a 220-volt source; the latter voltage is preferred. U1 and U2 are suppressors included to prevent transients from damaging the high-voltage capacitor bank or the rectifier diodes. Since T1 has two 117-volt primary windings, a suppressor is connected across each. The windings and suppressors are connected in parallel for 117-volt operation, and they are series connected for a 220-volt line.

A relay (K1) is necessary to switch the high-current inrush when the supply is activated. Ordinary toggle switches cannot be used to activate the power supply directly. Surge protection is accomplished by placing R1 in series with one lead of the ac line. K3B shorts out this resistor a few seconds after the main power switch (S1) is actuated. A separate line cord for the power supply allows this section to be operated on 220 volts while permitting other circuits in the amplifier to operate on 117 volts.

The Amplifier Circuit

A single 3-500Z triode tube develops 1-kW input on cw and 1-kW PEP on ssb. The output circuit is a conventional pi network which tunes the hf amateur bands from 3.5 to 30 MHz. The T-R switch, similar to the one used in the T-9er, is coupled to the tank circuit via C1. This capacitor is constructed of RG-8A/U and is 3 inches long.

Filament voltage is applied to the 3-500Z through a bifilar-wound rf choke. Drive power is coupled to the filament circuit via C2, a disk-ceramic capacitor.

Two Zener diodes are used to develop grid bias. S3C selects either CR18 for 27 volts (cw) or CR19 for a 7.5-volt bias (ssb). Since the lower bias voltage increases the standing plate current to approximately 80 mA, R7 is placed in series with the cathode-return lead to cut off the tube during standby periods. Protection for the power supply is assured by placing a 1-ampere fuse in series with the Zener diodes. This procedure could save a tube or a meter (not to mention power supply components!) in the event a high current surge or arc occurs in the output circuit.

The Multimeter

A 1-mA meter is used to measure grid current, plate voltage, and power output. R4, mounted on the rear chassis apron, allows adjustment of the

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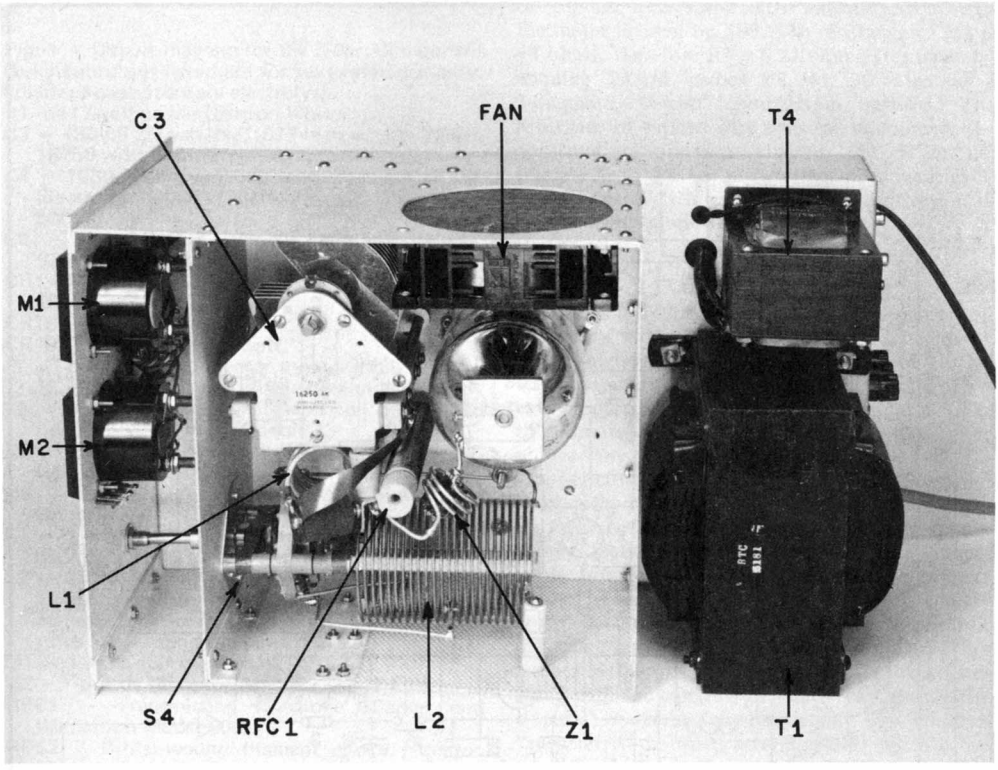
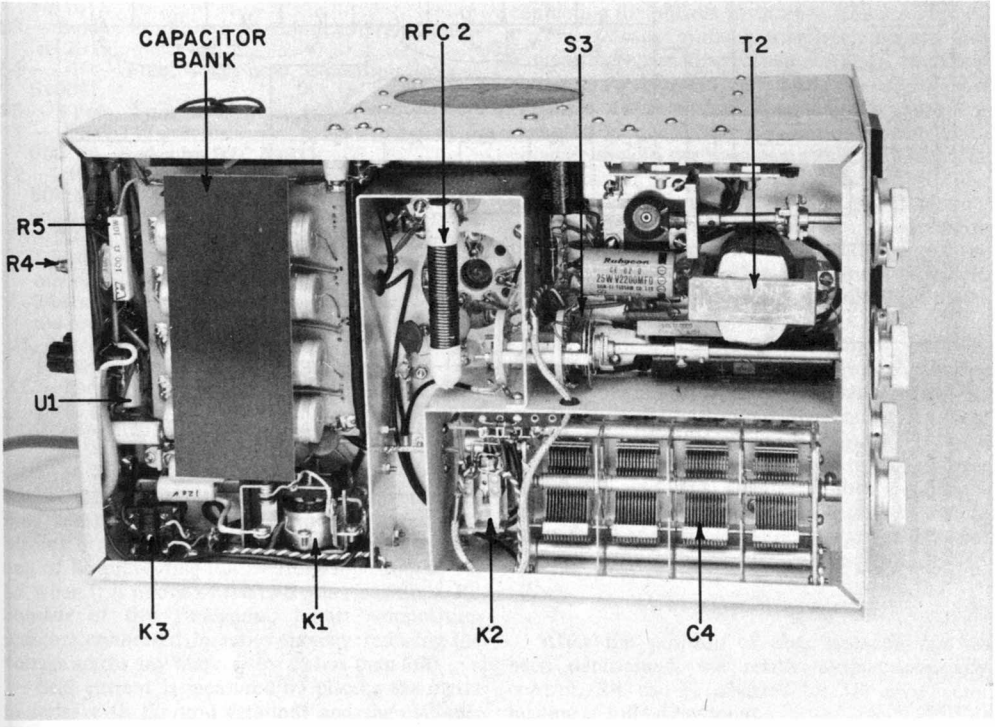


Top view.



Bottom view.

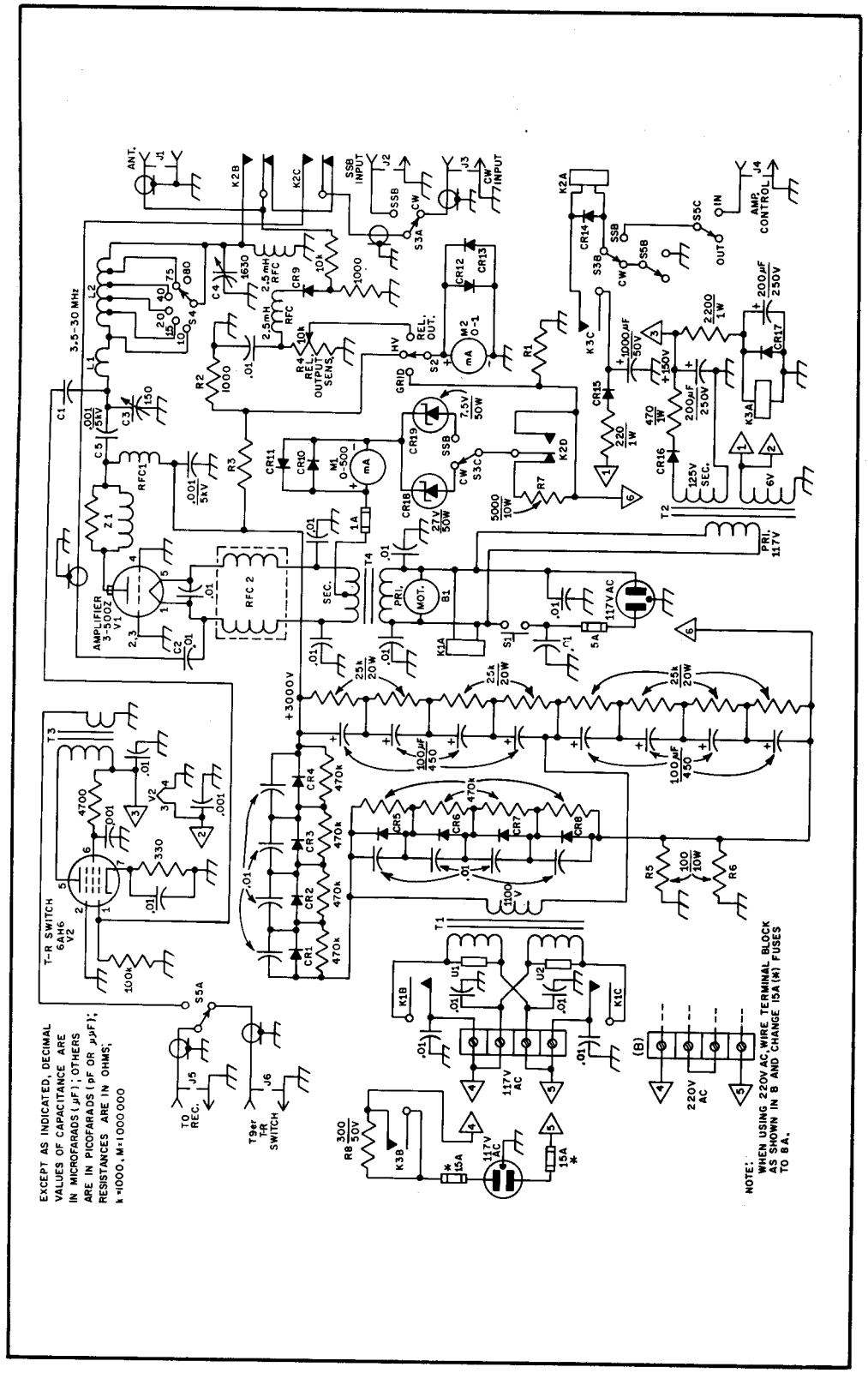

EXCEPT AS INDICATED, DECIMAL VALUES OF CAPACITANCE ARE IN MICROFARADS (μF); OTHERS ARE IN PICOFARADS (pF OR μμF); RESISTANCES ARE IN OHMS; k=1000, M=1,000,000
NOTE: WHEN USING 220V AC, WIRE TERMINAL BLOCK AS SHOWN IN B AND CHANGE 15A (*) FUSES TO 8A.
ANT.
J1
3.5-30 MHz
L1
L2
C1
C2
C3
C4
C5
Z1
V1
AMPLIFIER 3-500Z
RFC 1
RFC 2
R1
R2
R3
R4 REL. OUTPUT SENS.
R5
R6
R7
R8
M1 0-500 mA
M2 0-1 mA
CR1
CR2
CR3
CR4
CR5
CR6
CR7
CR8
CR9
CR10
CR11
CR12
CR13
CR14
CR15
CR16
CR17
CR18
CR19
T1
T2
T3
T4
T-R SWITCH 6AM6
V2
K1A
K1B
K1C
K2A
K2B
K2C
K2D
K3A
K3B
K3C
S1
S2
S3A
S3B
S3C
S4
S5A
S5C
SSB INPUT
J2
J3
CW INPUT
J4
AMP. CONTROL
J5
J6
TO REC.
T-R SWITCH
HV
GRID
REL. OUT.
+3000V
117V AC
220V AC
PRI. 117V
SEC.
MOT.
B1
5A
15A
1A
5000 10W
1000 V

Fig. 1 — Circuit diagram for the S-9er. Component designations not listed are for text reference only. Polarized capacitors are electrolytic.
B1 — 117-volt ac fan (Rotron Whisper).
C3 — 180-pF air variable, .077-inch air gap (Millen 16250 with 4 stator plates removed).
C4 — 1680-pF air variable, receiving type (R. W. Electronics, 4005 W. Belmont Ave., Chicago, IL 60641).
C5 — Transmitting capacitor, 1000-pF ceramic (Centralab 858S-1000).
CR1-CR17, incl. — 1000-PRV, 2.5-A (Mallory M2.5A or equiv.).
CR18 — Zener, 7.5-V, 50-watt.
CR19 — Zener, 27-V, 50-watt.
J1 — Coax chassic connector, type SO-239.
J2-J6, incl. — Phono jack, single-hole mount.
K1 — Power relay, dpdt, 117-volt coil (Potter and Brumfield PR-11AY or equiv.).
K2 — 4pdt, 5-A, 6-V dc coil (Potter and Brumfield GPD coil and GO-17 contact arrangement).
K3 — Dpdt, 10-A, 120-V dc coil (Potter and Brumfield KA11DG or equiv.).
L1 — 7 turns, 1/8-inch copper tubing, 1 1/4-inch dia, tapped at 3 turns from tube end.
L2 — 23 turns, No. 14, 2 1/2-inch dia, tapped at 10 3/4 turns for 40 meters, 17 1/2 turns for 20 meters, as measured from the C4 end. (Coil stock: Barker and Williamson 3029.)
M1 — 1-A dc (Simpson Model 2122-17400).
M2 — 1-mA dc (Simpson Model 2122-17430).
RFC1 — Transmitting rf choke (Barker and Williamson Model 800).
RFC2 — Bifilar-wound filament choke (Amidon 10-A choke kit or equiv.).
S1 — Spst push button (Calectro E2-144).
S2 — Single-pole, 3-position rotary (Calectro E2-161).
S3 — 3-pole, 2-position, 2-section, rotary (Centralab 2515).
S4 — Rf switch, single-pole, 6-position (Millen 51001).
S5 — 3-pole, 2-position, rotary (Calectro E2-165).
T1 — Dual 117-volt primary, 1100-V secondary, 600 VA (Berkshire BTC 6181).
T2 — 117-volt primary; secondary 125 volts at 50-mA; 6.3-V at 2-A (Stancor PA-8421 or equiv.).
T3 — 20 turns, No. 24 enameled wire wound on a 1-inch long, 1/2 inch dia iron core from a slug-tuned coil form. The secondary is 3 turns No. 24 enameled wire wound over the cold end of the primary.
U1, U2 — Transient voltage suppressor, 120-volt (General Electric 6RS20SP4B4).
Z1 — Parasitic suppressor, 3 turns No. 12 copper wire, 1 1/4-inch dia wound over three 150-ohm, 2-watt composition resistors.

relative-output circuit sensitivity. A voltage-dropping resistor network, R3, provides a full-scale reading of 5 kV. R2 maintains a load at the meter end of R3 preventing full B+ from appearing across S2 when it is in one of the two other positions. R3 consists of five 1-megohm, 1-watt composition resistors connected in series thereby reducing the voltage across any one resistor to less than 600.

Grid current is measured by placing the meter in series with the grid (ground) and the cathode. The meter shunt, R1, provides a full-scale reading of 500 mA. R1 is equal to the internal resistance of the meter divided by 500. The resistance of M1 is 43 ohms; therefore R1 is 0.21 ohm. It is made by winding 24 1/4 inches of No. 30 wire on a 1-megohm, 2-watt composition resistor. The resistance of various wire sizes can be found in the construction practices chapter. R1 is in the primary path for the high-voltage negative lead to chassis ground. R5 and R6 provide protection in the event this meter shunt opens.

Construction

The amplifier, including the power supply, is built on a 10 X 17 X 3-inch aluminum chassis. All of the high-voltage power supply components are mounted at the rear of the chassis. Location of the various parts is shown in the photographs. All of the circuits carrying rf are completely shielded to reduce any instability or TVI generation. The input-circuit shield is mounted between S3 wafers to keep the rf wiring inside the compartment.

Extreme care must be taken in the power supply section to keep the high-voltage components from coming in contact with the primary wiring. This section of the amplifier is very crowded. A sheet of 1/16-inch thick phenolic insulating material is placed between the capacitor bank and the chassis. The electrolytic capacitors, along with the equalizing resistors, are mounted on a piece of etched circuit board. This board is "suspended" between several solder lugs attached to ceramic standoff insulators. Rubber cement is used to hold a 1/2-inch thick piece of phenolic board to the capacitors to prevent them from contacting the bottom plate when it is installed.

The rf-output circuit is completely shielded in a compartment constructed of cane metal and sheet aluminum. Perforated material is needed to allow adequate air flow past the tube. The socket is mounted 1/2 inch above the chassis, allowing air to circulate around the base connections and seal. The grid pins of the socket are soldered to lugs mounted on the chassis.

When a standard Eimac plate cap is used with the 3-500Z, the cap extends above the edge of the cabinet. Therefore, a 1/4-inch thick aluminum plate, 1 3/4-inches square, is used in place of the Eimac unit.

The plate-tuning capacitor, C3, is vertically mounted and is adjusted from the front panel using a surplus right-angle drive. A Millen drive works equally well. C4 has a shaft diameter of 3/8 inch, requiring special attention. A standard 1/4-inch coupling with one end drilled out to slightly over 3/8 inch is used as an adapter. Fine-mesh screen is placed between the cabinet wall and the fan to maintain an rf-tight enclosure. The screen does not appear to reduce the air flow appreciably.

Operation

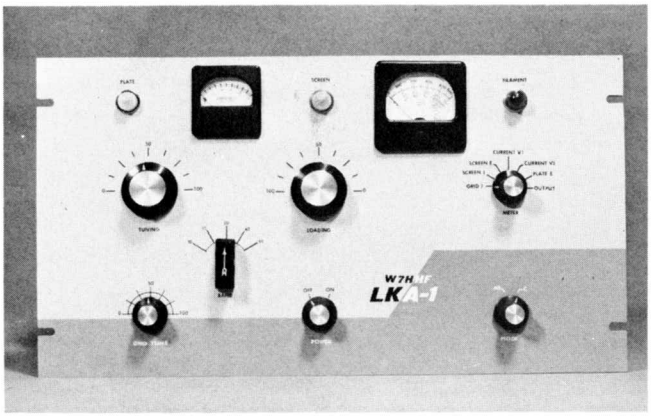
After the position of each tank-coil tap has been determined, the relative-output sensitivity control, R4, can be adjusted for 3/4 scale meter reading at full power input.

In order to determine the plate current, the grid

current must be subtracted from the cathode current. When the amplifier is driven to a grid current of 120 mA and the tuning controls are adjusted for maximum power output, the cathode current will be about 500 mA and the plate voltage will be slightly over 2500. This represents an input power of approximately 950 watts. After extended periods of operating or tuning, the fan should be left on for a few minutes to allow the tube to cool.

Fig. 1 shows several methods for interconnecting the station equipment. The exciter IN/OUT function is performed by S5B which deenergizes K2 to allow the exciter to feed through to the antenna. The appropriate T-R switch output is routed to the receiver by S5A. *Caution:* When S3 is in the cw position, there is no load connected to the ssb exciter input terminal. Likewise, there is no load on the cw input connector when S3 is in the ssb position.

The LKA-1



Linear Amplifier

BY CECIL C. COPE,* W7HHF

DURING RECENT YEARS, a number of transistorized transceivers and transmitters of various types have made their debut. These units are designed to operate QRP, and usually deliver from five to ten watts output. If one intends only to operate at low power, he need read no further. However, there are times when band conditions dictate the use of higher power.

The amplifier to be described, which covers 80 through 10 meters, should fill the bill nicely for those who wish to run higher power and use the low-power transmitter for an exciter. This amplifier uses 4CX250B tubes (which are more commonly used at vhf). It is capable of a full kilowatt input on ssb, cw and RTTY, provided the power supply has the capability for operation under the higher duty cycle encountered on RTTY. Drive requirements are very modest for this amplifier. In fact, drive conditions approach those of the venerable 6146. The author has been able to obtain very satisfactory results using a transceiver delivering only five watts.

Included in the design is provision for Class-C operation of the amplifier, thereby achieving maximum efficiency on cw and RTTY. Drive requirements for this mode are in the neighborhood of ten watts. Output efficiency is very high. According to the *RCA tube manual* rf-output ranges from 650 watts in Class AB1 to over 800 watts when operated Class C. While these figures may be a bit optimistic, experiments conducted by the author indicate that if tank circuit conditions are approximately correct, efficiency is very good. The prospective builder may note several unique features in this amplifier as shown in Fig. 1. The first is the screen supply. The second feature is the method of metering the various functions, and the third is the thermal time-delay relay circuit. Screen voltage for the amplifier is obtained from an electronically regulated supply. This was done primarily for two reasons. First, during normal operation the screens draw 60 mA which is more than the usual VR-tube string is capable of handling. Secondly, by using this type of supply, it is much easier to alter the screen voltage when changing from Class AB1 to Class C. An added advantage is that the screen voltage can be set to the exact voltage desired. The electronically regulated supply provides excellent voltage stability over its dynamic range.

Metering is rather unconventional in that the instrument is used as a voltmeter which measures the drop across the series resistors located in the various circuits. This was done to eliminate the need for winding meter shunts, a rather time consuming task. Accuracy is good using this method and no problems have developed. The series resistances are of sufficiently low value to cause no effect in operating conditions. In this amplifier, M1 is connected in the B– return (see Fig. 1) from the high-voltage supply and con-

* 2713 Dill Dr., Boise, ID 83705.

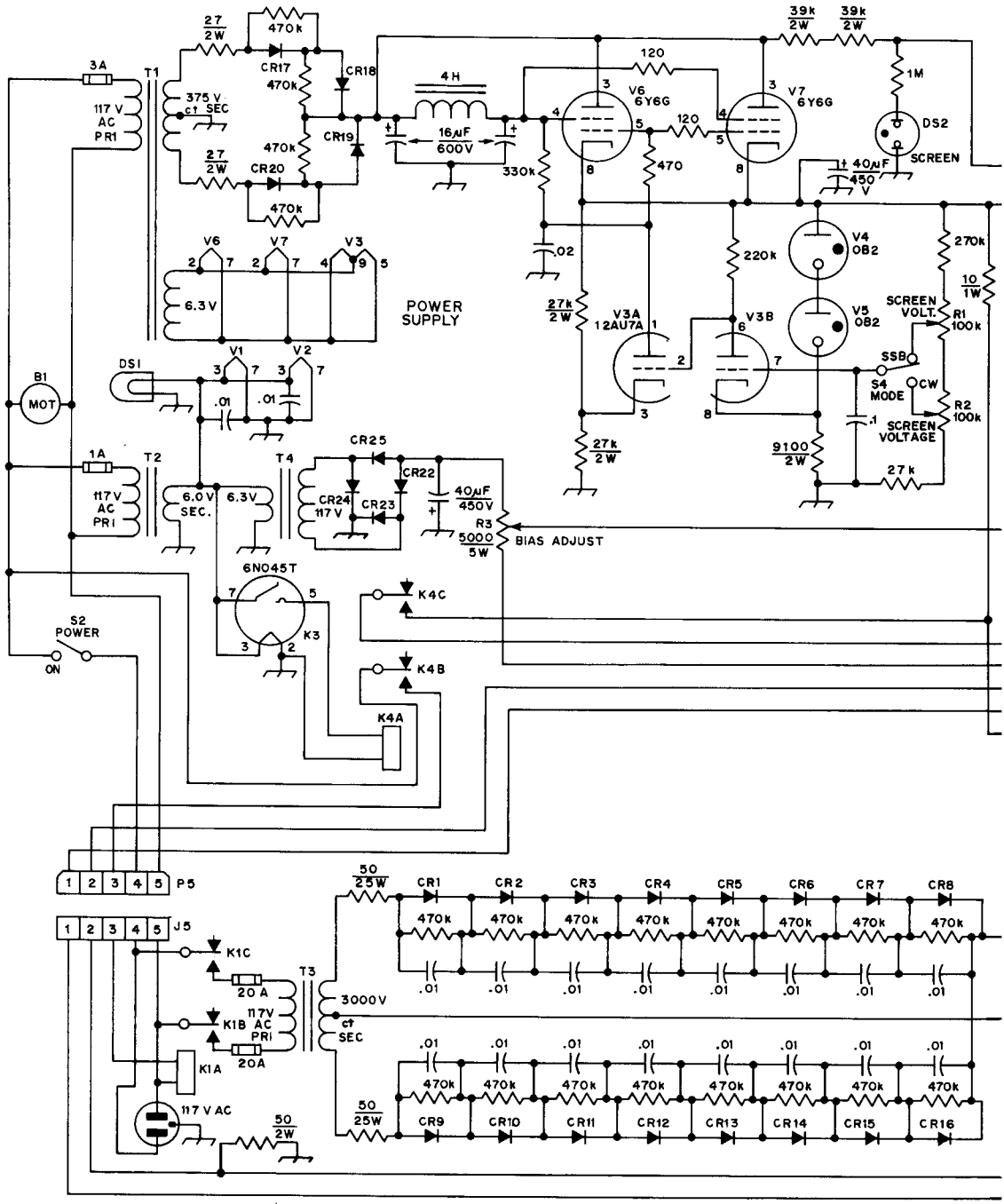


Fig. 1 — Schematic diagram of the amplifier. Unless otherwise specified, resistors are 1/2-watt composition and capacitors are disk ceramic.

C1-C6, incl. — Electrolytic (Mallory CG241T450DI).

C7, C8 — Four .01 disk ceramic capacitors connected to each of the cathode terminals (4) of each tube.

C9, C10 — See text.

C11 — Variable capacitor, 450 pF, 3 kV.

C12 — See text.

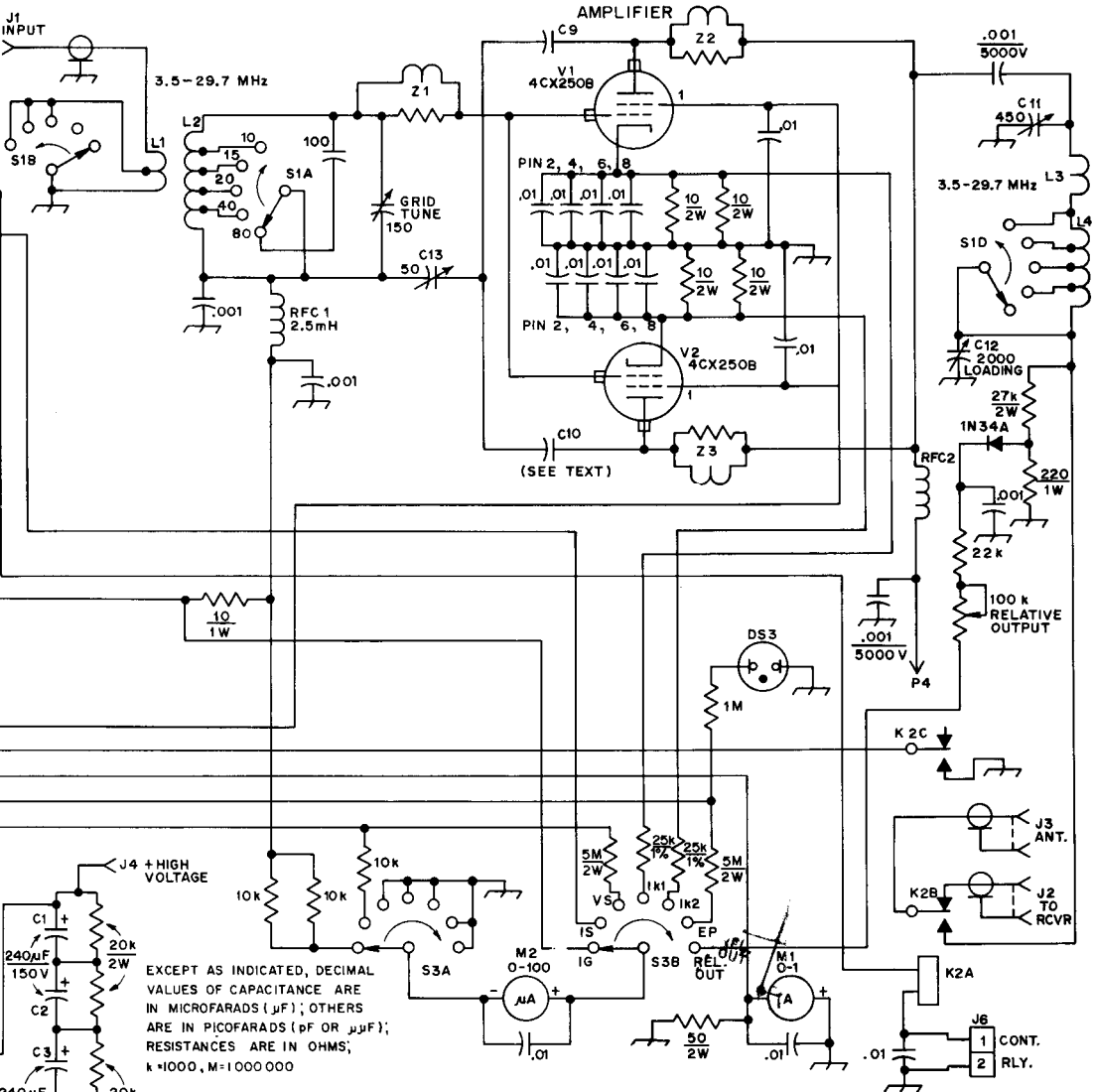
C13 — Small air variable, 50-pF.

CR1-CR23, incl. — Silicon diode, 1 A, 800 PRV.

K1 —Power relay, 20-A contacts, 117-V ac coil.

K2 — Antenna relay, 10-kΩ coil, dpdt, 5-A contacts (Potter and Brumfield GB11D).

K4 — Dpdt relay, 6.3-V ac coil, 5-A contacts (Potter and Brumfield KT11A).



L1 — Insulated hook-up wire, 4 turns around the low-frequency end of L2, 3 turns around the high-frequency end (total, 7 turns), tap at 4 turns from ground end.

L2 — Grid coil, 22 turns of No. 20, 1-1/4 inch diameter, 1-1/2 inches long. Taps at 10, 15, 17, and 19 turns from cold end.

L3 — Copper tubing, 1/4 inch dia., 1-1/2 inch OD, 2-1/2 inches long mounted at right angles to L4.

L4 — (See text) 10 turns of No. 8 copper wire and 4 turns 1/4-inch copper tubing, 3-3/8 inch dia., total length 5 inches. Taps at 7-1/2 9-1/2, and 10-1/2 turns from loading capacitor end. Ten-meter tap is made at the junction of L3 and L4.

RFC2 — Plate choke, 60 turns of No. 24 enam. wire close-wound on 3/4 inch plastic dowel stock. Dowel stock is drilled and tapped at one end for attachment to chassis.

T1 — Plate transformer, 375 V ct at 120 mA, 6.3 V at 4 A (Thordarson 25R08 or equiv.).

T2 — Filament transformer, 6.0 V at 6 A (Thordarson 21F73 or equiv.).

T4 — Filament transformer, 6.3 V at 1.2 A (Thordarson 21F09 or equiv.). T4 is connected in reverse. That is the 117-V winding supplies voltage for the bias supply.

Z1 — Five turns of No. 20 enam. wire over length of 220-ohm 1-W composition resistor.

Z2, Z3 — Four turns of No. 14 solid copper wire, 3/4 inch diameter, 3/4 inches long, wound over 2 paralleled 220-ohm, 2-W composition resistors.

screened openings are provided also in the tank-circuit compartment.

A circuit board located near the grid compartment supports the various resistors associated with the metering circuits. Another circuit board is used to mount the diodes, resistors, and other components used in the screen and grid-bias supplies. The transformers used in these supplies are mounted directly on the main chassis.

Controls which are mounted on the rear apron are as follows: the output voltmeter adjust and the grid-bias control. The neutralizing capacitor, C13, is accessible through a capped hole at the rear of the chassis. Connectors on the rear of the chassis include control connectors to the high-voltage supply, input/antenna/receiver coaxial-cable fittings, and the high-voltage connector. Front panel controls are as follows: plate tuning, plate loading, ac power, multimeter switch, mode switch and band switch. The screen-voltage adjust controls are located near the front panel, just below the multimeter on the main chassis. These are "set-and-forget" type controls, so ready access is not needed.

It should be pointed out that the grid-tuning capacitor must be isolated from ground, as bias voltage is present on the rotor. An insulated shaft with universal joints is used to connect this capacitor to its control knob on the front panel. All leads entering the grid and plate compartments, with the exception of rf carrying leads, are bypassed at the point of entry. This is accomplished best by the use of ceramic feedthrough capacitors.

Neutralization of the amplifier is acheived by the voltage-dividing network composed of C13, C9 and C10. C9 and C10 are aluminum plates, 1 × 4 inches long, fitted with a small bracket which is attached to a ceramic feedthrough bushing terminating in the grid compartment. C13 is connected in series with C9 and C10 which provides a means of adjusting the feedback to the proper amount. C9 and C10 are located 3/8 inch from the radiators of the 4CX250B-tubes.

The plate-circuit rf choke (RFC2) is home-made. Plastic dowel stock is used for the coil form and is drilled and tapped for attachment to the chassis. A cutout is made in the chassis which is used to conduct the output of the blower to the chassis compartment. Brackets for the blower are formed from aluminum stock, and exact dimensions will depend on the blower model used.

The blower on this amplifier is a 110 cubic-foot-per-minute "squirrel-cage" type. Blowers of smaller capacity may be used, but it must be kept in mind that this type of device normally loses efficiency because of back pressure. The tubes present considerable resistance to air flow and using a blower with a rather high output ensures that adequate cooling is accomplished under all conditions.

Operation

After construction is complete and a check performed for wiring errors, disable the high-voltage and screen supplies by removing the appropriate fuses. Be sure that no high-voltage is present before proceeding. One word of caution: *under no circumstances should the amplifier be operated with the bottom plate removed.* The 4CX250Bs require a flow of cooling air at all times to maintain tube seal temperatures within specified limits. Be sure that the blower is operating and that the tubes are receiving adequate air flow before high voltage is applied.

Apply filament voltage. Using the bias-adjust control, set the grid bias to −50 volts. The amplifier may now be neutralized. Procedures for accomplishing this are covered thoroughly in *The Radio Amateur's Handbook* and other sources, so further details will be omitted here. After neutralization is complete, screen and plate voltages may be connected to the amplifier. Using the multimeter in the screen-voltage position and with the mode switch set for AB1, adjust R1 for a reading of 350 volts. Switch to the Class-C mode and adjust R2 for 250 volts. The amplifier is now ready for operation.

When used as a Class AB1 amplifier, the proper amount of drive occurs at the point which almost produces a flow of grid current. Current flow indicates that the amplifier is being overdriven – a condition which is to be avoided. Quickly load the amplifier until screen current is at an indicated 60 mA. When this has been done, operation is close to optimum. Avoid running the amplifier under maximum drive and minimum loading conditions for more than a short time, as screen dissipation is excessive during these periods.

Class-C operation is accomplished in the following manner: switch the MODE switch to the Class-C position. Apply drive to the amplifier until an indicated 25 mA of current flows in the grid circuit. Load the amplifier for 60 mA screen current. As with the Class AB1 mode, conditions approach optimum at this point. No adjustment is made to the grid-bias control for Class-C operation. The bias voltage is raised to the proper level by the flow of grid current through the bias-control potentiometers.

Conclusion

The amplifier seems to function well over a wide range of plate voltages. In fact, it was operated for a period of time with only 500 volts on the plates. It has provided many hours of operation with a supply delivering 1100 volts. Of course, maximum output and efficiency will be achieved when the power supply produces a full 2000 volts at approximately 500 mA.

This amplifier has proven to be a very stable and efficient one. No problems of any sort have been encountered with parasitic oscillations, and TVI has been almost nonexistent. The only known case of TVI has occurred due to overloading of the front end of the author's TV set – a condition caused mainly by the close proximity of the TV antenna to the "antenna farm."

(Continued on page 158)

Linear Amplifier *(continued from page 43)*

Nothing really new or revolutionary is claimed for this amplifier. It is presented mainly in the hope that it will provide an answer to a gap which exists today in amplifier design. With this amplifier, the owner of a low-power exciter need not go to an intermediate amplifier to obtain the power needed to drive the more common grounded-grid amplifiers so much in vogue today. However, the amplifier is of sufficient complexity so as to make it impractical as a project for the beginner. But for the experienced constructor with a few pieces of equipment under his belt, it should prove to be an enjoyable and worthwhile undertaking. QST

A 160-METER AMPLIFIER

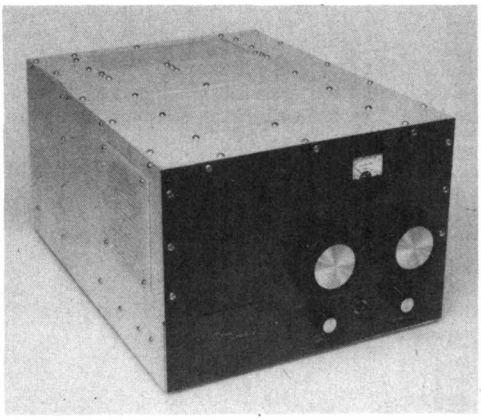


Fig. 1 — Front view of the 160-meter amplifier. Note the use of perforated aluminum stock to permit ventilation of both the rf and power supply compartments. The large front-panel knob on the right controls C3, while the adjacent knob to the left controls C2. The power switch, S1, is controlled by the smaller knob located beneath C3. Both S1 and S2, the meter switch, are mounted below the chassis, and DS1 is mounted between the two switches.

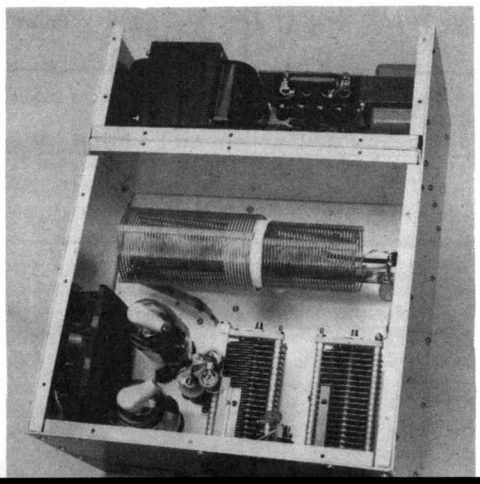
Anyone who has operated in the 160-meter band lately can attest to the fact that interest in the "top band" is on the upswing. With only a handful of manufacturers producing gear for 160, this band is somewhat of a "homebrewers' haven." Most operation takes place during the evening hours, because the high level of daytime ionospheric absorption makes communication (other than strictly local) all but impossible for low powered stations. Summertime static makes things even more difficult. At present, amateurs occupy this band on a shared basis with various radionavigation services, with maximum input power limitations imposed to prevent harmful interference from occuring. These restrictions are greatest between sundown and sunrise, when the potential for interference is at maximum. However, during the daylight hours, amateurs in 29 states are permitted to use up to 1000 watts power input, while in the other 21, the maximum is 500 watts, in selected segments of the band.[1] The amplifier described below is for use with 160-meter exciters in the 50- to 100-watt output class, for ssb and cw operation.

Circuit Data

A pair of 572B/T160L triodes are used in a cathode-driven, grounded-grid configuration (see Fig. 3). A small amount of operating bias is provided by the 3.9-volt, 10-watt Zener diode in series with the cathode return lead, and the tubes are completely cut off during nontransmitting periods by opening that lead with K1A to reduce unnecessary power consumption and heat generation. The other contacts on K1 perform all necessary antenna switching functions for transceive or separate transmitter/receiver operation. Drive power from the exciter is fed to the directly heated cathodes through a parallel combination of three .01 μF disk capacitors, and a resonant cathode tank circuit helps minimize the amount of drive required. The filament choke, RFC2, isolates the driving signal from the filament transformer. A B&W FC-15A choke was used here. A single power switch, S1, applies 117 V ac to the primaries of both the power and filament transformers simultaneously, as the 572B's require no significant warmup time. S1 also activates the cooling fan, B1, and the front-panel pilot light assembly, DS1. The self-contained high-voltage power supply uses a straightforward voltage doubler circuit. No-load voltage is approximately 3100 V dc, dropping to 2600 V dc under one kilowatt key-down conditions. R2 limits the initial surge current to the filter capacitor bank to prevent exceeding the current handling capability of the rectifier string when the supply is first turned on.

A single 0-1 mA meter is used to monitor either plate voltage or cathode current. To measure plate voltage, a multiplier consisting of five series-connected 1-megohm 1-watt resistors with one end tied to the B plus line is switched in series with the meter to provide a full-scale reading of 5000 volts. A 1000-ohm one-watt resistor between the bottom of the meter multiplier and ground prevents the full B plus voltage from appearing across the meter switch, S2, when it is in the other position. To measure cathode current, the meter is placed in

Fig. 2 — Top view of the amplifier. The rf components occupy the foreground, while the heat-generating power-supply components are visible behind the compartment shield at the rear.



[1] A chart of U.S. and Canadian 160-meter sub-allocations is available from ARRL Headquarters; send a stamped, self-addressed envelope and request form S-15A.

Fig. 3 — Circuit diagram for the 160-meter amplifier. Fixed-value capacitors are ceramic disk unless otherwise indicated. Polarized capacitors are electrolytic. All resistors are 1/2-watt composition unless noted otherwise.

B1 — 117-volt axial fan (Rotron Whisper Fan or equiv.).
C1 — Parallel combination of one 5000, 2000, and 1000-pF silver-mica capacitors.
C2, C3 — 250-pF air variable, .075-inch spacing (E. F. Johnson 154-9 or equiv.).
C4, C5, C6 — Transmitting capacitor, 1000-pF "doorknob" (Centralab 858S or equiv.).
CR1-CR12, incl. — 1000 PRV, 2.5-A silicon (Motorola HEP 170 or equiv.).
DS1 — 117-volt ac neon pilot lamp assembly.
J1 — Phone jack.
J2, J3 — Coax chassis-mounting connector, type SO-239.
K1 — 3pdt, 10-A contacts, 110-V dc coil (Potter and Brumfield KUP14D15 or equiv.).

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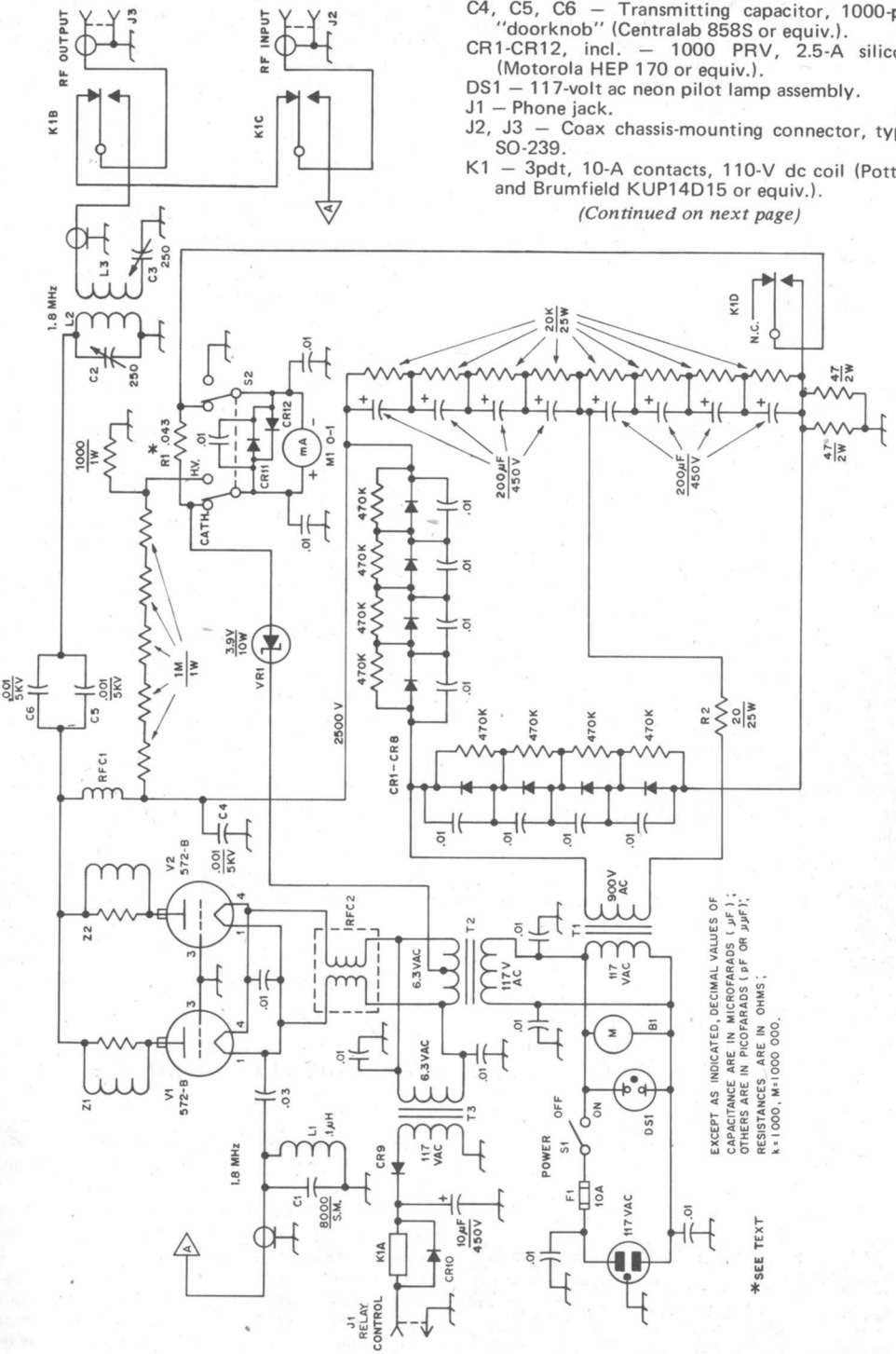


L1 – 1.0 μH
L2, L3 – See text.
M1 – 1-mA dc (Simpson model 2121 or equiv.).
RFC1 – 1.0 mH, 500 mA (E. F. Johnson 102-752 or equiv.).
S1 – Spst rotary switch.
S2 – Dpdt rotary switch.
T1 – 117-volt primary; secondary 625-0-625 volts ac (ct not used) at 450 mA (Hammond No. 720).
T2 – 117-volt primary; secondary 6.3 V ct at 10 A (Stancor P-6464 or equiv.).
T3 – 117-volt primary; secondary 6.3 V ac.
VR1 – Zener, 3.9-V, 10-watt (Motorola HEP Z3500 or equiv.).

parallel with shunt R1, which remains in series with the cathode return lead at all times. To obtain a full-scale reading of one ampere, a shunt resistance of .043 ohms was used with the Simpson model 2121 meter, as it has an internal resistance of 43 ohms (see Chapter 17).

As this amplifier is designed for monoband operation, the mechanical and electrical complexities and compromises involved in the band-switching of an output network are not a factor here. Tuned-link coupling is used in the output circuit. The grid of each 572B is tied directly to chassis ground, using short leads, to avoid problems with instability. Parasitic suppressors Z1 and Z2 also contribute to stability. Neutralization is not necessary.

B&W Miniductor stock is used at L2 and L3. L2 is made from 43 turns of B&W 3034 (No. 14 wire, 8 tpi, 3-inch dia.) and L3 is made from 39 turns of B&W 3030 (No. 14 wire, 8 tpi, 2-1/2-inch dia.). The coils are supported on a 10-inch strip of bakelite which is mounted on three 1-1/2-inch steatite insulating cones. L2 is epoxied into place on the side of the bakelite strip nearest the tubes. L3 will be partially inserted into the cold end of L2, and is epoxied into place after initial adjustments have been made. L3 must be able to slide freely inside L2 without making electrical contact. The first 10 turns of L3 may be covered with a layer of Scotch No. 27 glass insulating tape. Leads from L3 are made with teflon-insulated flexible stranded wire to allow the coil a degree of freedom of movement during initial adjustment. Rf output from L3 is connected to K1B through a short length of RG-58/U coaxial cable.

Meter shunt R1 is made by winding 12-1/2 inches of No. 26 enam. wire around a 1-megohm 2-watt resistor. If the meter used has an internal resistance other than 43 ohms, the appropriate shunt resistance value may be wound by referring to the copper wire resistance table in Chapter 18.

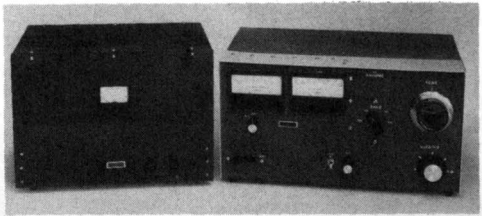
Parasitic suppressors Z1 and Z2 are each made with 3-1/2 turns of No. 14 enam. wire wound around the parallel combination of three 82-ohm, 1-watt composition resistors, mounted right at each plate cap.

Operation

The power supply should be tested before rf drive is applied to the amplifier. For initial tests, it is desirable to control the power transformer primary voltage with a Powerstat, while leaving the filament transformer primary and fan connected directly to the 117 V ac line. *Remember at all times that lethal voltages exist both above and below chassis.* Do not make any internal adjustments with the power on, or even with the power off until the bleeders have fully discharged the filter capacitors (at least 40 seconds with this particular amplifier). It is good practice to clip a lead from the B-plus terminal to ground after the capacitors have discharged, whenever working inside the amplifier (remember to remove it before applying power!). The tuned-input circuit (L1-C1), should be checked with a grid-dip meter for resonance at the frequency segment of interest. K1 must be closed during transmit; this may be effected by shorting the wire from J1 to ground with a relay inside the 160-meter exciter, or with an external switch. Starting with a plate voltage of about 1500 volts, drive is applied through J2 and C2 is adjusted for maximum rf output as indicated on an external rf wattmeter or relative output indicator. C3 is then adjusted for maximum output. The plate voltage may now be advanced to its normal level. The link may be moved in or out (with power off) and C2 and C3 again adjusted until the highest efficiency is obtained. At that point the link, L3, may be epoxied in place. In the amplifier described here, the optimum position for L3 was when eight of its turns were inside L2. This may be used as a starting point for the adjustment. Normal tune-up procedure involves only the adjustment of C2 and C3 for maximum output, within the maximum legal power limits, of course. During normal operation the 572B anodes may glow with a dull red color. The tubes draw about 50 mA resting current, when K1 is closed and no drive is applied.

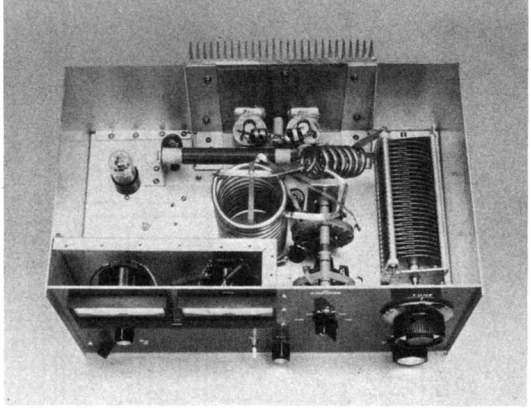
A CONDUCTION-COOLED TWO-KILOWATT AMPLIFIER

One of the major concerns when dealing with high power amplifiers is heat and how to reduce it. The usual method has been to use a large fan or blower, but this solution is generally noisy. By using the principles of heat transfer, a noiseless amplifier can be made with the use of an adequate heat sink and conduction-cooled tubes.



The amplifier shown in the photographs and schematically in Fig. 1 uses a pair of recently designed 8873 conduction-cooled triode tubes. The circuit configuration is grounded grid and uses no tuned-input tank components. When properly adjusted, the amplifier is capable of IMD characteristics which are better than can be achieved by a

A 2-kW Amplifier



Top view of the 80-through 10-meter conduction-cooled amplifier. The chassis is 17 × 12 × 3 inches (43.2 × 30.5 × 7.6 cm) and is totally enclosed in a shield. A separate partition was fabricated to prevent rf leakage through the meter holes in the front panel. An old National Radio Company vernier dial is used in conjunction with the plate tuning capacitor to provide ease of adjustment (especially on 10 meters). The position of the dial for each band is marked on the dial skirt with a black pen and india ink.

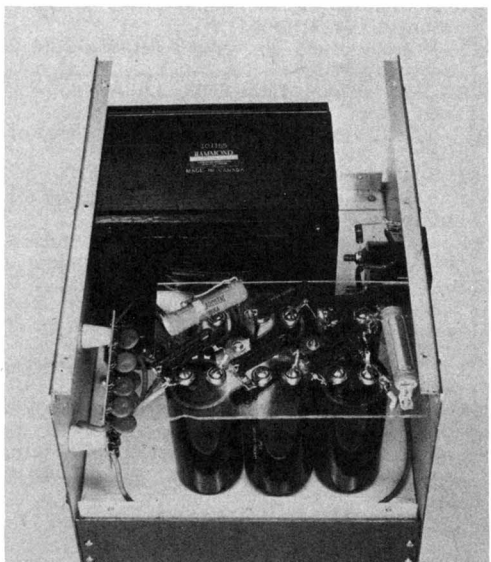
typical exciter, therefore the added complexity of band switching a tuned-input circuit was deemed unnecessary.

Construction

Building an amplifier such as this is often an exercise in adapting readily available components to a published circuit. For this reason, a blow-by-blow description of this phase of the project will not be given. An effort was made, however, to use parts which are available generally, and should the builder desire, this model could be copied verbatim.

The most difficult constructional problem is that of aligning the tube sockets correctly. It is imperative that the sockets be aligned so that when the tubes are mounted in place, the flat surfaces of the anodes fit smoothly and snugly against the thermal-link heat-transfer material. Any misalignment here could destroy the tubes (or tube) the first time full power is applied. The mounting holes for the tube sockets are enlarged to allow final positioning after the tubes are "socked" in place with the clamping hardware. Pressure must be applied to the anodes so that they are always snug against the thermal link. The hardware used to perform this function must be nonconducting material capable of withstanding as much as 250°C. The pressure bracket used here was fabricated from several Millen jack-bar strips (metal clips removed) mounted in back-to-back fashion. The entire assembly is held in place by means of a long piece of No. 10 threaded brass rod which passes through a small hole in the center of the heat sink. An attempt to give meaningful comments about how tight the tubes should be pressured to the copper and aluminum sink will not be given. Suffice it to say that the tubes should fit flat and snugly against the thermal hardware. The heat sink was purchased from Thermaloy and is connected to a 1/4-inch thick piece of ordinary copper plate. The total cost for the copper and the aluminum sink is somewhat more than the price of a good centrifugal blower ($30) but the savings offered by not having to purchase special tube sockets and glass chimneys overcomes the cost differential.

The power supply is built on a separate chassis because the plate transformer is bulky and cumbersome. A special transformer was designed for this amplifier by Hammond Transformer Co. Ltd., of Guelph, Ont. Canada. The transformer contains two windings, one is for the plate supply to be used in a voltage-doubler circuit and the other is for the tube filaments. The power supply produces 2200 volts under a load of 500mA, and is rated for 2000 watts. The Hammond part number is given in Fig. 1. All of the interconnections for power-supply control and the operating voltages needed by the amplifier are carried by a seven-conductor cable. This excludes the B plus, however, which is connected between the units by means of a piece of test-probe wire (5-kV rating) with Millen high-voltage connectors mounted at both ends. The seven-conductor cable is made from several pieces of two-conductor household wire (No. 10) available at most hardware stores. Since the main power switch is mounted on the front panel of the amplifier, the power supply may be placed in some remote position, out of the way from the operator (not a bad idea!). A high-voltage meter was included with the power supply so that it could be used with other amplifiers. It serves no purpose with this system. The main amplifier deck has provisions for monitoring the plate voltage.



Top view of the power supply built by WA1JZC showing the technique for mounting the filter-capacitor bank. The diodes are mounted on a printed-circuit board which is fastened to the rear of the cabinet with cone insulators and suitable hardware.

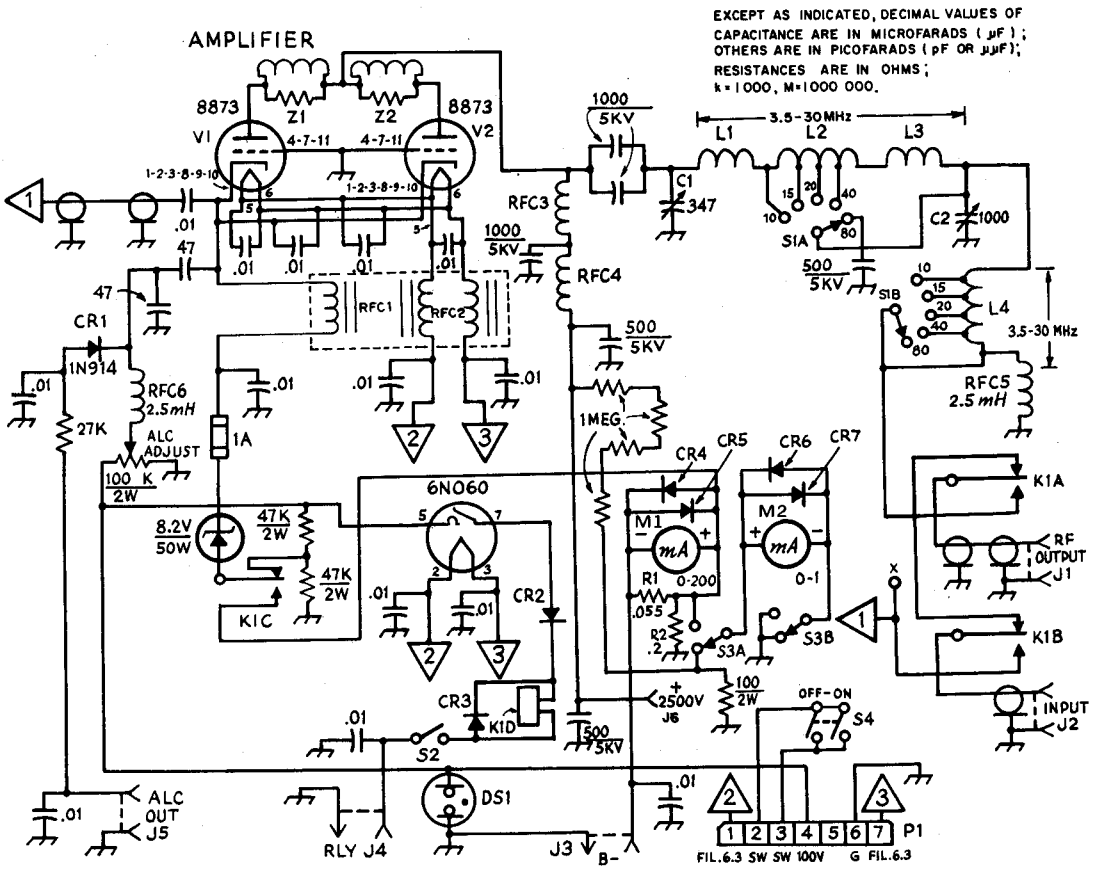


Fig. 1 — Circuit diagram for the 8873 conduction-cooled amplifier. Component designations not listed below are for text reference. RFC1 and RFC2 are wound on the same ferrite rod in the same direction; three wires are wound together (Amidon MU-125 kit). Tube sockets for V1 and V2 are E.F. Johnson 124-0311-100. The thermal links are available from Eimac with the tubes. The heat sink is part number 2559-080-A000 from Astrodyne Inc., 353 Middlesex Ave., Wilmington, MA 01887, and costs approximately $20.

C1 — Transmitting air variable, 347 pF (E.F. Johnson 154-0010-001).

C2 — Transmitting air variable, 1000 pF (E.F. Johnson 154-30).

CR2-CR7, incl. — 1000 PRV, 2.5 A (Motorola HEP170).

J1 — SO-239 chassis mounted coaxial connector.

J3, J4, J5 — Phono jack, panel mount.

J6 — High-voltage connection (Millen 37001).

K1 — Enclosed, three-pole relay, 110-volt dc coil (Potter and Brumfield KUP14D15).

L1 — 4-3/4 turns of 1/4-inch copper tubing, 1-3/4-inch inside diameter, 2-1/4 inches long.

L2 — 12-1/2 turns, 1/4-inch copper tubing, 2-3/4-inch inside diameter, tap at one turn from connection point with L1, 2-1/2 inches for 20 meters, 7-3/4 turns for 40 meters.

L3 — 11-1/2 turns, 2-inch diameter, 6 tpi (Barker and Williamson 3025).

L4 — 10 turns, 2-inch diameter, 6 tpi, with taps at 3 turns for 10 meters, 3-1/2 turns for 15 meters, 4-3/4 turns for 20 meters, 6-3/4 turns for 40 meters; all taps made from junction of L3 (Barker and Williamson 3025).

M1 — 200 mA full scale, 0.5-ohm internal resistance (Simpson Electric Designer Series Model 523).

M2 — 1 mA full scale, 43 ohms internal resistance (Simpson Electric, same series as M1).

R1 — Meter shunt, .05555 ohms constructed from 3.375 feet of No. 22 enam. wire wound over the body of any 2-watt resistor higher than 100 ohms in value.

R2 — Meter shunt, 0.2 ohms made from five 1-ohm, 1-watt resistors connected in parallel.

RFC1, RFC5, RFC6 — 2.5 mH (Millen 34300-2500).

RFC3 — Rf choke (Barker and Williamson Model 800 with 10 turns removed from the bottom end).

RFC4 — 22 μH (Millen 34300).

S1 — High-voltage band-selector style, double pole, six position (James Millen 51001 style).

Z1, Z2 — 2 turns 3/8-inch-wide copper strap wound over three 100-ohm, 2-watt resistors connected in parallel.

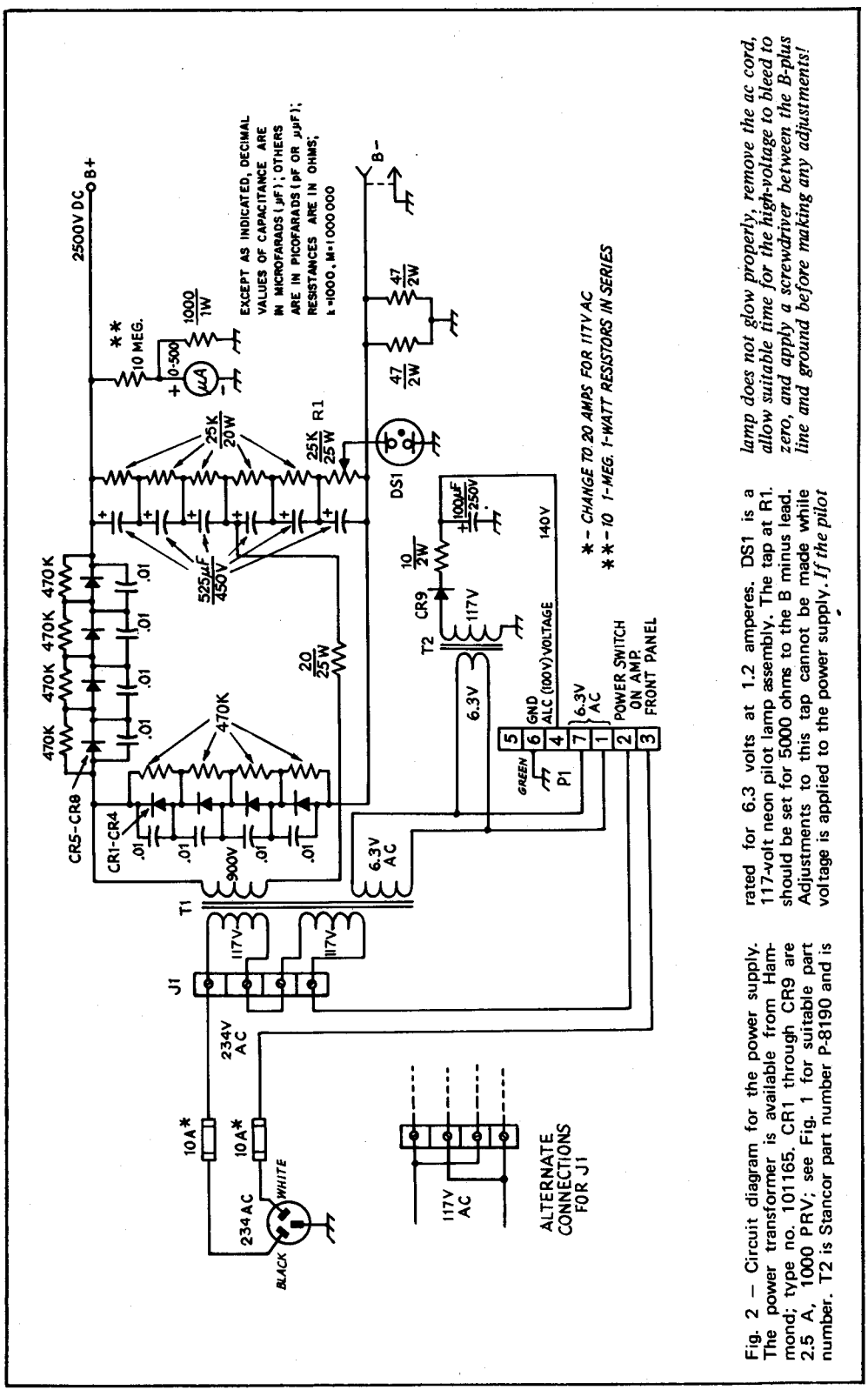


Fig. 2 — Circuit diagram for the power supply. The power transformer is available from Hammond; type no. 101165. CR1 through CR9 are 2.5 A, 1000 PRV; see Fig. 1 for suitable part number. T2 is Stancor part number P-8190 and is rated for 6.3 volts at 1.2 amperes. DS1 is a 117-volt neon pilot lamp assembly. The tap at R1 should be set for 5000 ohms to the B minus lead. Adjustments to this tap cannot be made while voltage is applied to the power supply. *If the pilot lamp does not glow properly, remove the ac cord, allow suitable time for the high-voltage to bleed to zero, and apply a screwdriver between the B-plus line and ground before making any adjustments!*

A conventional household light switch may be used for S4. If the switch is to be mounted horizontally, be sure to use a contactor device and not a mercury type (which operates in a vertical position only). A double-pole switch was used with both poles connected in parallel. The rating is 220 V at 10 A per section.

The RF Deck

The two sections of the pi-L network are isolated from each other by placing one of them under the chassis. Although not shown in the photograph, a shield was added to prevent rf energy from entering the control section underneath the chassis. The shield divides the chassis between the tube sockets and the inductors. The loading capacitor is mounted directly beneath the plate-tuning capacitor. This scheme provides an excellent mechanical arrangement as well as a neat front-panel layout.

The 8873s require a 60-second warmup time, and accordingly, a one-minute time-delay circuit is included in the design. The amplifier IN/OUT switch is independent of the main power switch and the time delay. Once the delay circuit "times out," the amplifier may be placed in or out of the line to the antenna, whenever desired. A safety problem exists here: there is no large blower running, and there are no brightly illuminated tubes to warn the operator that the amplifier is turned on. Except for the pilot lamp on the front panel, one might be fooled into believing the amplifier is turned off! And if the pilot lamp should burn out, there is *absolutely* no way to tell if the power is turned on (with the resultant high voltage at the anodes of the 8873s). *Beware!*

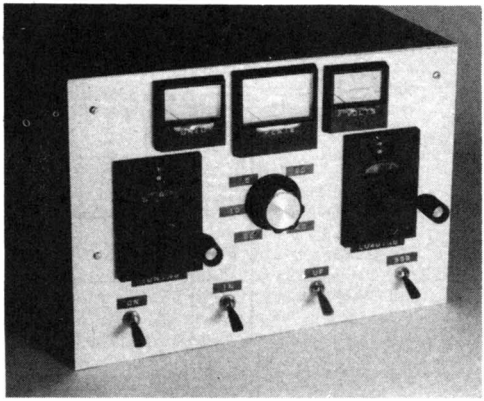
Operation

Tuning a pi-L-output circuit is somewhat different than tuning a conventional pi-network because the grid current should be monitored closely. Grid current depends on two items, drive power and amplifier loading. The procedure found to be most effective is to tune for maximum power output with the loading sufficiently heavy to keep the grid current below the maximum level while adjusting the drive power for the proper amount of plate current. The plate current for cw operation should be 450 mA and approximately 900 mA under single-tone tuning conditions for ssb. This presents a problem since it is not legal to operate under single-tone tuning conditions for ssb. Sixty watts of drive power will provide full input levels. For use with high-power exciters, see *QST* for October, 1973.

A TWO-KILOWATT AMPLIFIER USING THE EIMAC 8877 TRIODE

One of the easier projects for the amateur to undertake is the construction of an amplifier for use on the hf bands. Generally speaking, the mechanical aspects of the construction are more difficult to handle than the electrical ones. And, as with any construction project, acquiring the parts can be difficult. The two-kilowatt amplifier shown here is designed for dependable service at the maximum legal power input allowed in the United States. The component ratings are generous and the construction is heavy duty. Since power handling capability is typically determined by physical size, most of the components used here are large and accordingly, a split arrangement has been employed allowing the placement of the power supply on a separate chassis from the amplifier compartment.

Another feature sets this amplifier apart from most others described in the literature; the air is exhausted from the top of the tube socket instead of the conventional pressurized chassis air-flow system.



Front view of the 8877 amplifier. The non-sequential numbering of the band switch is discussed in the text. A switch is provided to allow the selection of proper bias for the mode in use at the time.

The Circuit

The triode, a 3CX1500/8877, is connected in a grounded-grid configuration which provides about the most simple layout possible. The output tank circuit is a pi-network with vacuum-variable capacitors used for both input and output tuning. A 2.5-mH rf choke is connected between the output

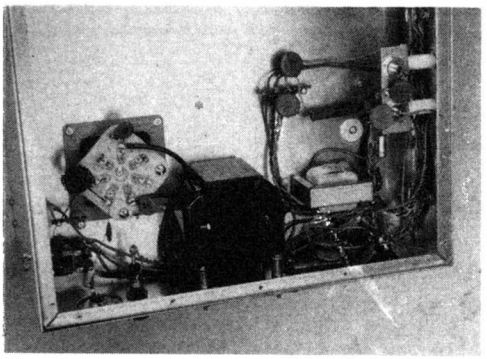
end of the tank and ground to prevent B plus from appearing at the antenna terminals should C1 develop a short.

A passive, untuned, capacitor-coupled circuit is used to apply rf-drive energy to the 8877 cathode. Since a moderate amount of bias is permitted, L1 is incorporated to provide isolation from rf to the bias-developing Zener diodes. The highest recommended bias voltage for use on ssb is 8.2, but for cw operation, where IMD is not important, 22 volts is developed which nearly places the tube at cutoff (zero no-signal plate current). A 10-kΩ resistor is included in series with the Zener-diode circuit to assure complete cutoff of the 8877 during receiving periods. It is switched out of the circuit during transmit periods by a set of contacts on K1.

Antenna transfer along with bias switching is accomplished with two relays. Sequencing can be an important factor since it is very undesirable to provide drive to the 8877, remove its bias, all before the output circuit relay has closed and stopped "bouncing." This is accomplished by the use of a vacuum relay shown as K2 in Fig. 1. K2 is many times faster in operation than K1 and accordingly, the antenna is placed on the amplifier output circuit well ahead of drive arriving at the cathode of the 8877. Voltage to operate both relays is developed by T2. Since the relays are connected in a fashion to allow straight-through operation of an exciter or transceiver to the antenna in the de-energized position, interruption of the voltage from T2 during transmit periods with it is undesirable; to have the amplifier "on line" and developing power, is all that need be done. S4 serves that function.

Metering of three operating conditions of the amplifier is accomplished with three meters instead of one or two. The purpose is first, to eliminate a switch for selection, and second, to provide continuous indication of the important parameters of the 8877. Of course, operator error is reduced since it is impossible to assume a meter is measuring one thing while a switch is selected for another. Both plate and grid current meters are direct-reading instruments – no shunts are needed. A string of resistors is used at R1 to multiply the scale of the 500-μA meter to indicate zero through 5000 volts. R1 is constructed of 10 resistors, one-watt in size and one-megohm in value. The purpose is to keep the applied voltage across each resistor below 600. A 1000-ohm resistor is included at the meter end of R1 to keep the voltage low should the meter winding become an open circuit.

Another feature of this particular amplifier is the use of a motorized Powerstat for control of the high-voltage circuit. The ability to select the operating plate voltage from the front panel of the amplifier is a feature desired by the builder of the project and need not be duplicated. If voltage control is not used, the power transformer used in the high-voltage power supply should be selected to provide about 3000 volts. This is a suitable compromise for efficient cw and ssb operation at the maximum power input levels. In actual operation, the amplifier shown in the photographs is used with 3400 volts during ssb operation and 2500 volts for cw conditions.



Bottom view of the amplifier chassis. L1 is shown near the tube socket. It is wound on a T-50-2 Amidon toroid core. The Zener diodes are mounted on a plate and secured to the side chassis wall.

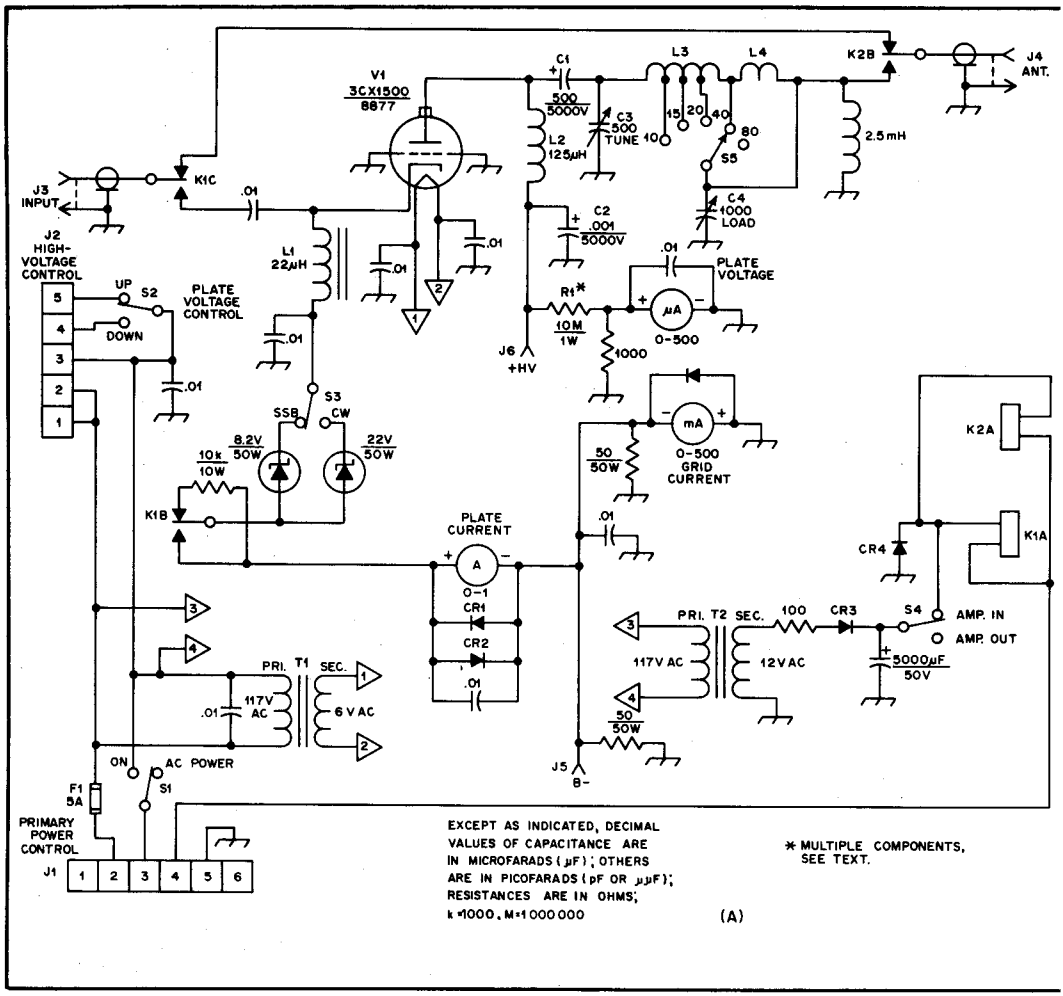
Several 50-ohm, 10-watt resistors have been placed at various points in the B-minus circuit, both in the amplifier-chassis compartment and on the power supply chassis. This prevents the B-minus lead from creeping above "almost ground" potential should a defect develop in the grid-current metering circuit. Also, included in the B-plus lead is a 10-ohm resistor which will help prevent component damage should a direct short take place in the amplifier compartment.

Mechanical Construction

The split-chassis configuration offers several advantages. First, it allows the amplifier compartment to be somewhat more compact because the power supply can be located elsewhere. This consumes less space on the operating desk. It also divides the weight into parts; the heavier section may be placed on the floor. The power supply may be equipped with wheels to give it mobility. The only disadvantage with having a two chassis system comes when portability is desired.

The power supply has been assembled on an aluminum plate which is 1/4-inch thick. Casters are provided because the plate transformer itself weighs about 80 pounds. The capacitor bank for filtering has also been mounted on the aluminum plate. A circuit board is used to interconnect the capacitors and is supported above the plate with ceramic pillar insulators. A screened covering is provided to keep unwanted objects from contacting the high-voltage system. The power supply relay (T3 primary connection) and the Powerstat have been assembled separately and may be interconnected to the power supply chassis plate via an inconnecting cable. Mounting both the plate transformer and the Powerstat on the same chassis would render it unmovable!

The power supply bleeder-resistor network



EXCEPT AS INDICATED, DECIMAL VALUES OF CAPACITANCE ARE IN MICROFARADS (μF); OTHERS ARE IN PICOFARADS (pF OR μμF); RESISTANCES ARE IN OHMS; k=1000, M=1 000 000

* MULTIPLE COMPONENTS, SEE TEXT.

(A)

must be placed in a position to allow air to flow past it and rise through the top screen cover. R2 and R3 each consist of six resistors (12 total) rated at 20-kΩ and 20 watts each. A similar bank of 12 capacitors connected in series constitutes the filter network. Each filter capacitor in the circuit has one of the bleeder resistors connected directly across it in order to assure equal voltage division. Each capacitor is rated at 200 μF and 450 volts.

CR5 and CR6 consist of series diodes similar in hookup to the capacitor and resistor network described above. Each individual diode is rated at 1000 volts; the four series connected equal 4000 PRV. The current rating for each diode is two amperes.

No provisions have been made to operate this plate supply from a 117-volt ac source. Accordingly, if one wishes to have such capability, a suitable transformer must be substituted for T3 shown in Fig. 1. It should be pointed out, however, that the plate supply is the only portion to operate with a 234-volt line. The amplifier filament circuit and voltage-source circuits for the relays along with the blower all operate from 117 V ac.

The amplifier portion of this system is constructed on an aluminum chassis which is 14 X 17 X 4 inches. The 14-inch dimension was chosen as the front-panel side to conserve space on the operating table. A bottom cover for the chassis is cut from a large section of aluminum perforated stock while the area above the chassis top is completely sealed and made airtight. The amplifier top cover is solid stock but has a four-inch flange (stovepipe material) mounted directly above the 8877 tube. Hot air is exhausted via this port using an external "blower" which has been set up to draw air rather than force it. The procedure is simple; just connect the four-inch hose coming from the pipe flange to the blower intake port. Place the blower exhaust outlet in a position so that it will not be restricted. The cold air is drawn in under the amplifier chassis, passes through the 8877 and socket, then out the stovepipe to the blower. The air from the blower is heated and

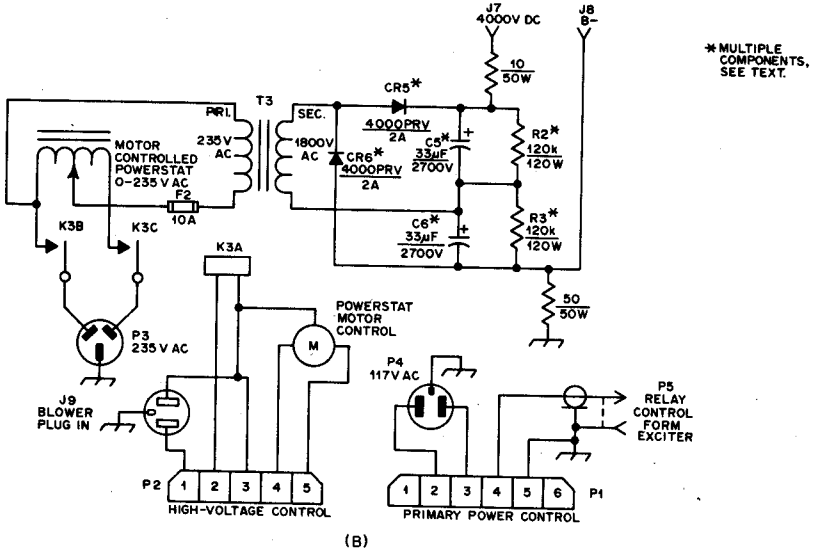


Fig. 1 — Circuit diagram for the 8877 two-kilowatt amplifier. Component designations not listed below are for text reference only.

C1 — 500-pF transmitting capacitor, 5000 volts (Centralab 858 series).

C2 — .001-μF transmitting capacitor, 5000 volts (Centralab 858 series).

C3 — Vacuum variable, 500 pF maximum, 7500 volts.

C4 — Vacuum variable, 1000 pF maximum, 5000 volts.

C5, C6 — Six 200-μF units (See text.).

K1 — Dpdt, 5-A contacts. Coil voltage is 12 volts dc.

K2 — Vacuum relay, spst. (Torr Electronics TFI or equiv.)

K3 — Power relay, 10-A contacts, 117-V ac coil.

L1 — 25 turns wound on an Amidon T-50-2 toroid core.

L2 — 125 μH, 2 A (Hammond Mfg.).

L3 — Strap-wound inductor, 12 μH total tapped at 2-1/2 turns for 10 meters, 3 turns for 15 meters, 5 turns for 20 meters and 14 turns for 40 meters. (E. F. Johnson 232-626).

L4 — 5 turns of 1/4-inch copper tubing wound the same diameter as L3.

S1, S3, S4 — spst, 3 A (Radio Shack).

S2 — spdt, 3 A with spring return to center off position (Radio Shack).

T1 — primary 117 V ac, secondary 5.0 V ac, 10 A. (Hammond Transformer).

T2 — primary 117 V ac, secondary 12 V ac at 3 A.

T3 — plate transformer, 234-volt ac primary, 1770-volt (Hammond Transformer 105677).

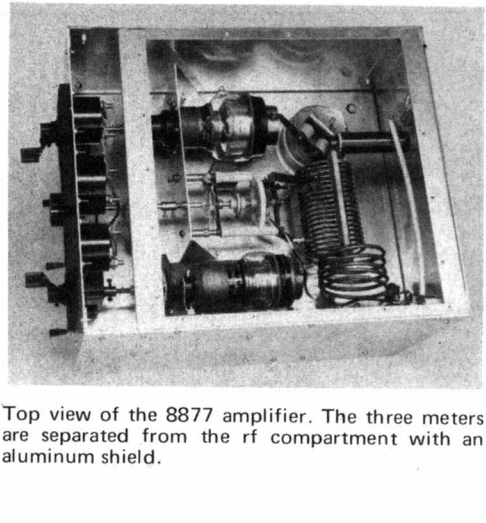
should not be directed at anything which might run normally warm (power supply components). In fact, the warm air may either be directed out of the radio shack in the event the heat is undesirable or the heat may be applied to one's feet in the winter season if the system is being used in an unheated basement atmosphere. Of course, one of the key features of a solid shield enclosure for the rf compartment is the reduction of unwanted radiation of fundamental or spurious energy which could cause TVI.

Care must be given to the mechanical installation of the high-voltage connectors and the cable used to transport 3600 volts of dc from the power supply to the anode of the 8877. Millen high-voltage connectors were used throughout. One problem developed during the testing phase of this project. A steel screw and nut were used to mount one of the connectors and apparently the Bakelite material cracked during installation. A discharge path developed across the crack creating loud noises and popping fuses. Nylon or Teflon hardware is recommended for mounting the Millen connectors if voltages above 3000 are anticipated.

Operation

Since this project is one which should not be undertaken by an inexperienced builder, some of the basic steps of pretest will not be discussed in detail here. Suffice it to say that ordinary primary voltage checks and switching should be confirmed as being in correct working order before placing primary power to the high-voltage supply. The 3000-volt circuit *must* be treated with respect — it can seriously injure or even kill a person coming in contact with it! Operation of the motor-controlled Powerstat can be determined by operating the system on the 117-volt primary, leaving the plug to the 234-volt line disconnected.

A word of caution: *The air flow system must always be used when any power is applied to the 8877 — even filament.* And rf drive power should



Top view of the 8877 amplifier. The three meters are separated from the rf compartment with an aluminum shield.

never reach the 8877 *unless* that tube has plate voltage applied. Of course, if one applies plate voltage and drive, he should be prepared to dissipate the power output from the amplifier into a dummy load of suitable rating.

One particular disadvantage of having the amplifier completely enclosed in a solid shield is the inability of the operator to visually spot any arc or component failure. During the initial testing of this amplifier, occasionally an arc would occur. While the arc was audible, the operator had to inspect the inner compartment very carefully to determine the cause of the malady. In fact, the arc had to be "encouraged" to a point where damage was easily identified!

Actual operation of the amplifier is quite simple. A feature which simplifies tuneup is the use of turn-counting dials for both the plate tuning and plate loading. Once the proper tuning has been established, one can log the numbers and return to them anytime. It is quite easy to touch up the dial settings for proper operating conditions once the approximate settings have been determined.

the grid current shows 40 mA, and maximum output power occurs in conjunction with a "dip" in plate current and a "peak" in grid current all at the same time as the plate tuning control is adjusted. A condition of high grid current is usually a result of insufficient loading or too much drive power. If a low grid current condition exists and loading control decrease doesn't correct it, more drive power is indicated.

Tuneup for single sideband at the two-kilowatt level can be done only during dummy load conditions because it requires key-down conditions in excess of the legal-limit power restrictions. There is no way to tune this amplifier into an antenna at reduced power input and then drive it up to the two-kilowatt rated input point. The procedure for adjustment is identical to the one described above for cw operation. The one exception is plate-power input as indicated by the meters should be two kilowatts. Then, when the proper settings have been determined, the ssb drive signal is adjusted so that peak readings of plate current show about one half of that shown for key-down operation.

The lack of a tuned-input circuit solves several problems normally encountered when constructing an amplifier. The main advantage is that there need not be two band-switch decks with long leads (or even worse, two band switches!) nor space given to the inductors and capacitors. The driving impedance of the 8877 is very nearly 50 ohms and requires very little power to drive it to full power input. The tuned-circuit characteristics would reduce the drive requirement even further and should be considered by anyone wishing to use a 20-watt driver. For those amateurs using modern-day exciters in the 100-watt output class, some reduction in exciter gain control may be necessary. Exciters with more than about 150 watts of output power available should not be used without due consideration being given to an attenuator. The measured power required for this particular amplifier and tube shown was 50 watts to achieve a kilowatt on cw and about 70 watts for two kilowatts (this was in conjunction with a plate voltage change between modes) for ssb service. Slightly more drive power was required on 10 meters.

Problems

Some of the difficulties which come with making an amplifier of this category operate correctly are worthy of mention. First, as discussed earlier, some components which seemed adequate for 2500-volt systems failed when 3600 volts of dc was applied. The Millen connectors were one example. While the failure was not the fault of the component, care must be given to the maintenance of insulation integrity. Rf voltages developed in the tank circuit of this unit are substantial. Several problems with the band-switch contacts were encountered. Even though the plate output inductor has unused turns shorted out by the band switch, the shorted section of the coil can (and

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most likely will) have extremely high voltages present on it. In order to solve an arcing problem one of the band-switch tap positions had to be swapped with another. The band-switch markings on the front panel are not sequential. A solution to the problem would no doubt come if one were to use a continuously shorting switch.

Another difficulty which plagued this constructor was the propensity for the amplifier to show large amounts of negative grid current on 80 meters along with erratic plate current and poor efficiency. The calculated value for L2 is 95 μH. The original choke used at this point measured 87 μH even though an inductance of 95 was called for. After many hours of tank-circuit troubleshooting, it was decided to change the plate choke. The new one had an inductance of 125 μH and the 80-meter problems disappeared.

Collecting the Parts

Most of the component parts used in the project were purchased from surplus dealers or were donated by the manufacturer. Special thanks to James Millen Inc., Hammond Transformer Corporation, Simpson Electric, and Eimac for keeping the total cost of the parts to well within the allowable limits of any ARRL Lab project.

AN AMPLIFIER FOR QRP TRANSCEIVERS

The circuit of Fig. 1 shows a 15-watt output plug-in amplifier suitable for use with the HW-7 transceiver, or with any 2-watt class rig designed for hf-band work. The nucleus of the circuit is Motorola's new MRF-line transistor, the 449A. Unit cost is $13 for the part, and it will deliver up to 30 watts of output to 30 MHz as a Class C amplifier. Operating voltage is 13.0 dc. Rf drive requirements for full output are under 1 watt. Another member of this transistor family is the MRF450A, which will provide 50 watts of output with 2 watts of drive. It costs $16.50 according to a quote from an East Coast supplier.

Table I lists L and C values for 15 watts of output. The network is based on a loaded Q of 4. The X_L and X_C values given in Fig. 1 can be used to obtain inductance and capacitance values for frequencies other than 7, 14, and 21 MHz.

A 50-ohm, 3-dB attenuator pad is used at the amplifier input to assure less than 1 watt of drive without the need to modify the output stage or driver of the HW-7. The base shunting resistors of Q1 consume additional drive power while aiding amplifier stability. Another advantage of the attenuator is that it provides a resistive termination for the HW-7 across its operating range – 7 to 21 MHz. Without the attenuator the complex input impedance of Q1 would be reflected through T1, and the reactance seen by the HW-7 could be troublesome. A complex X_L and X_C condition exists at the input of a power transistor, and reactance amounts vary with operating frequency.

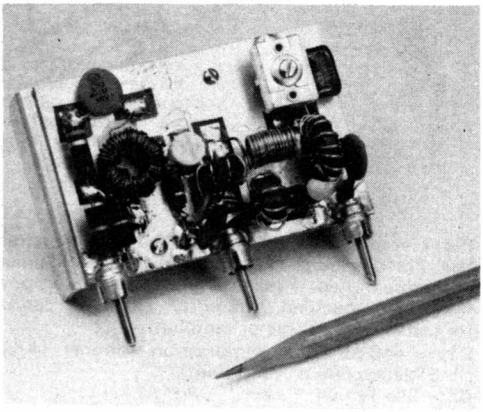
Circuit Notes

A *conventional* broadband toroidal transformer is used at T1. Equal performance was noted when comparing this transformer to *transmission-line* transformers. The latter consisted of two 4:1 transformers in cascade, effecting the desired 16:1 transformation ratio. A conventional transformer requires but one toroid core, and it is easy to build. For that reason it is specified here.

RFC1 serves as a low-Q collector choke, RFC2 is used as a decoupling choke to prevent rf energy from entering the HW-7 via the 13-volt line.

Performance

Motorola rates the MRF449A at 50-percent efficiency. Our lab findings bring that figure closer to 60 percent at 15-watts output. The output waveform from the circuit of Fig. 1 is exceptionally "sanitary." No distortion could be seen on the sine wave, as viewed on a 50-MHz scope, while delivering 15 watts into a 50-ohm dummy load.



Shown here is the assembled amplifier as originally described in *QST* for December, 1975.

A 1500-W-Output Amplifier for 160 Meters

Until a few years ago, most commercially available power amplifiers included no provision for top-band operation. With low sunspot numbers, 160 meters has become a great DX band. Sometimes a barefoot transceiver just isn't enough, and an amplifier is needed to make the QSO. The project described here and shown in Figs. 51 through 57 can enhance DX possibilities for those amateurs with an older five-band HF amplifier. It uses an EIMAC 3CX1500A7/8877 in grounded-grid configuration and will develop 1500 watts PEP output with 2500 volts on the plate. The amplifier is easy to drive, 50 to 60 W for full output, so any of the 100-W transceivers will do the job. Dick Stevens, W1QWJ, designed and built this project.

Fig. 51 — The 160-meter amplifier is built behind a 19- × 7-inch rack panel. Meters with bezels add to the clean appearance of the unit.

Circuit Details

The schematic diagram is shown in Fig. 52. The RF deck includes everything except the high-voltage power supply. Several suitable supplies are described elsewhere in this book. See Chapters 27 and 31, and the six-band 8877 HF amplifier described later in this chapter for ideas on building a high-voltage supply.

The input circuit (C7, L1, C8) is a low-Q pi network. No filament choke is needed with the 8877, which further simplifies the circuit.

The plate circuit is a pi network designed for a Q of 12. The tuning capacitor consists of a 300-pF fixed value (C17) in parallel with a 241-pF variable (C18). L2 is a section of standard Barker and Williamson coil stock. The loading capacitor consists of a 1600-pF fixed value (C20) in parallel with a 1000-pF variable (C19).

C13 bypasses the B+ line. Although an 8-kV unit was used here, any value above 4 kV should work fine. RFC2 is a Millen 1-mH, 1-A transmitter plate choke. RFC3 is included for safety to ground the high voltage that would appear at the antenna connector if dc blocking capacitor C16 fails.

Filament inrush current protection is provided by R1 and K1 in the T1 primary. After the initial current surge, K1A shorts out R1, applying full filament voltage. Power is applied to DS2, indicating that the filaments are on. T1 is a 5.0-V, 10.5-A transformer made by Avatar Magnetics. The primary is tapped to allow for precise adjustment of the filament voltage at the tube pins.

A grid overcurrent trip circuit is included to protect the 8877 from damage. The cost of an 8877 makes protection circuitry a must! Grid current is sensed across R5. If the grid current exceeds a preset value, Q1 conducts and actuates K2. Contact K2A, in the K3 coil supply line, opens and removes power from K3, placing the amplifier in STANDBY. To restore normal circuit operation, turn S3 to the off position; this will reset K2. S3 is "on" for normal operation. This switch provides an additional function: It controls the VOX circuit and antenna bypass relay circuit, so the amplifier can be switched in and out of the line between antenna and transceiver.

Zener diode D5 provides operating bias for the 8877. During receive periods, R6 is in the circuit, and the tube is cut off. For transmit, K3A shorts out R6.

All metering is done in the negative return lead for safety. C5, C6, D3 and D4 protect the meters. The antenna bypass relay (K4) is located externally but is powered from the amplifier.

Construction

The amplifier uses parts that are not too hard to find and are often available at flea markets at a very reasonable price. All components are, however, available commercially if the builder chooses that route. Most of the parts used in this project were purchased from Radio Shack, Electronic Emporium and RadioKit. See Chapter 35 for addresses.

Although an EIMAC SK-2200 series socket could be used, the socket used for this amplifier was homemade. It is built around a Johnson type 247 and an aluminum plate. Complete details of this plate, along with a full-size template, are shown in Fig. 53. This socket assembly can be made with hand tools — there is no fancy or complex metal work required.

Figs. 54 and 55 show the top and bottom of the chassis of the completed amplifier. Construction of a single-band amplifier is significantly easier than that of a multiband unit. Layout is not critical, and there is plenty of room to spare.

The amplifier is built on a 2 × 17 × 13-inch (HWD) aluminum chassis (Bud AC-419). This chassis is bolted to a standard 19 × 7-inch rack panel (Hammond PBPA 19 007). The top and side panels are formed from a single piece of perforated sheet metal often found at hardware stores.

Fig. 54 shows the top of the chassis. The 8877 is located along the back edge, near the center. C18 is mounted along the left-hand edge of the chassis, and the fixed capacitors that make up C17 mount directly behind C18. Details of the mounting plate for C17 are given in Fig. 56. C19 is mounted to the right of C18, and the capacitors that make up C20 mount to the chassis behind C19. L2 is mounted on an acrylic strip that is supported above the chassis by two ceramic standoff insulators. J3 and J5 mount to an aluminum bracket that bolts to the rear of the chassis.

The blower and filament transformer may be seen along the right-hand edge of the chassis. M1 and M2 mount to the front panel near the filament transformer. K1 and K3 mount in sockets between the filament transformer and the front panel.

Fig. 55 shows the underside of the chassis.

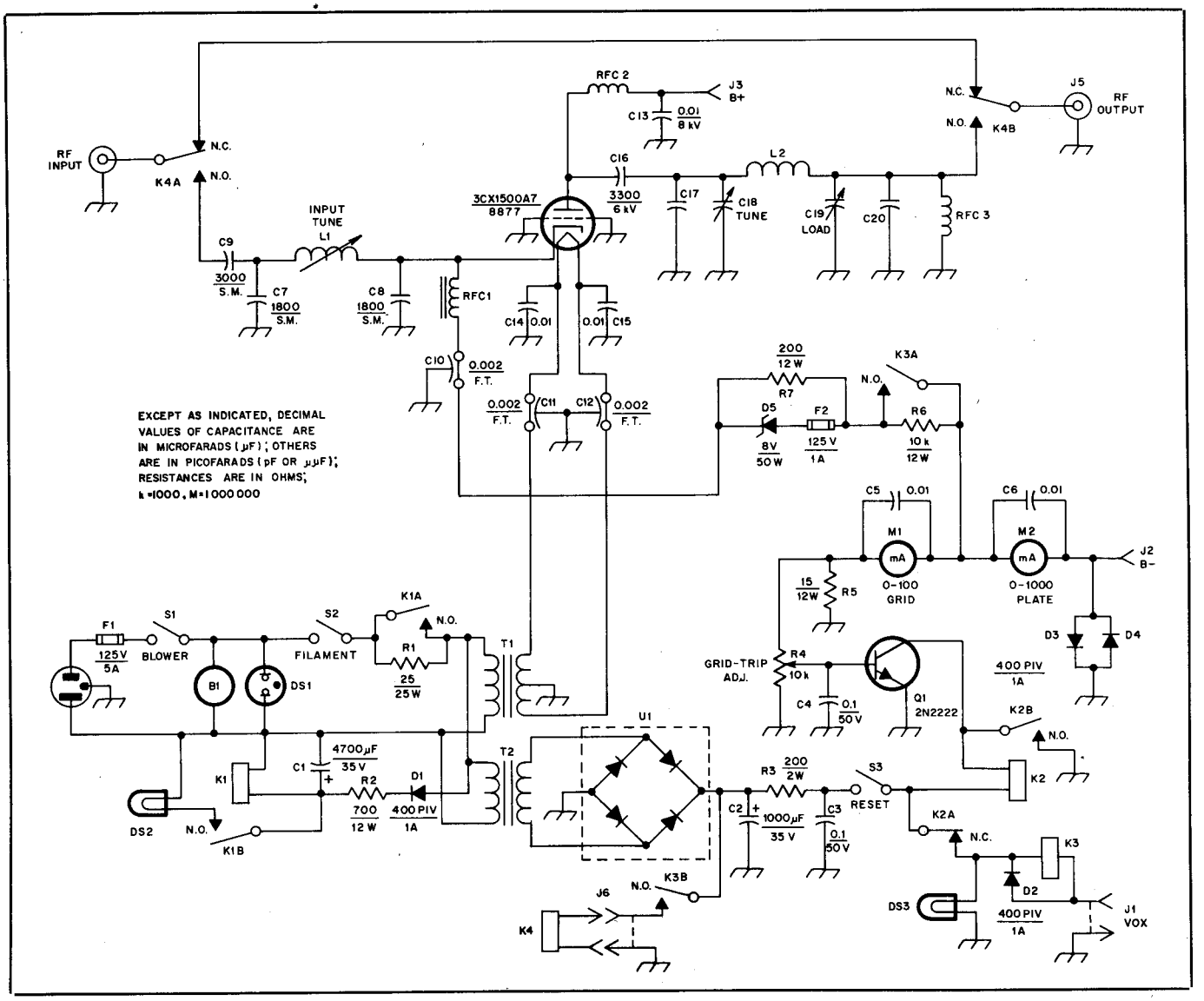


Fig. 52 — Schematic diagram of the 160-meter amplifier. Capacitors are disc ceramic unless otherwise noted. S.M. means silver-mica. Capacitors marked with polarity are electrolytic.

B1 — Dayton 4C012A 54-CFM blower.
C7, C8 — 1800-pF silver-mica capacitor; made from a 1500-pF unit in parallel with a 300-pF unit.
C9 — 3000-pF, 400-V silver-mica capacitor.
C10, C11, C12 — 0.002-μF, 8-kV feedthrough capacitor (Erie 1202-005 or equiv.).
C13 — 0.01-μF, 8-kV ceramic capacitor.
C16 — 3300-pF, 6-kV ceramic doorknob capacitor.
C17 — Three 100-pF, 5-kV ceramic doorknob capacitors in parallel.
C18 — 241-pF, 4.5-kV air variable capacitor (Cardwell 154-16 or equiv.).
C19 — 1000-pF, 1.5-kV air variable capacitor (Cardwell 154-30 or equiv.).
C20 — Two 800-pF, 5-kV ceramic doorknob capacitors in parallel.
DS1 — 117-V ac pilot light.
DS2, DS3 — 12-V dc pilot light.
J1 — Female chassis-mount phono jack.
J2, J3 — Millen 37001 high-voltage connector.
J4, J5 — Chassis-mount SO-239 connector.
J6 — Two-pin chassis-mount Cinch-Jones connector.
K1 - DPDT relay, 12-V dc coil, 10-A contacts, socket-mount.
K2 — Subminiature DPDT relay, 12-V dc coil.
K3 — DPDT relay, 12-V dc coil, 3-A contacts.
L1 — 4.4 μH; 25t no. 24 enam. on a ½-inch-OD, slug-tuned ceramic coil form.
L2 — 20 μH; 17t no. 12 tinned, 3-inch ID, 6 turns per inch (B&W 3033 miniductor stock or equiv.).
M1 — 0-100 mA meter.
M2 — 0-1000 mA meter.
RFC1 — 100-μH RF choke.
RFC2 — 1-mH, 1000-mA transmitting type RF choke (Miller 4534 or equiv.).
RFC — 2.5 mH, 200-mA RF choke (Miller 4537 or equiv.).
T1 — Filament transformer. 117-V ac primary; 5-V, 10.5-A center-tapped secondary (Avatar AV-434 or equiv.). Available from Avatar Magnetics, 1147 N. Emerson St., Indianapolis, IN 46219.
T2 — Power transformer. 117-V ac primary; 12.6-V, 1.2-A secondary.
U1 — 50-PIV, 4-A bridge rectifier.

An enclosure is fashioned around the input circuit for shielding and to direct the air flow up through the socket. The blower draws air from behind the amplifier and blows it into the input compartment. A homemade chimney, fashioned from Teflon sheet, directs air through the tube cooler. A suitable chimney, part number SK-2216, is available from EIMAC.

L1 mounts to the rear chassis wall so the input match can be adjusted with the covers on. Filament and bias voltage enter the input compartment through feedthrough capacitors. D5 mounts to a chunk of scrap aluminum bar for heat sinking. The grid overcurrent components (Q1, K2) are arranged on a small piece of perforated board. R4 is mounted to the chassis near

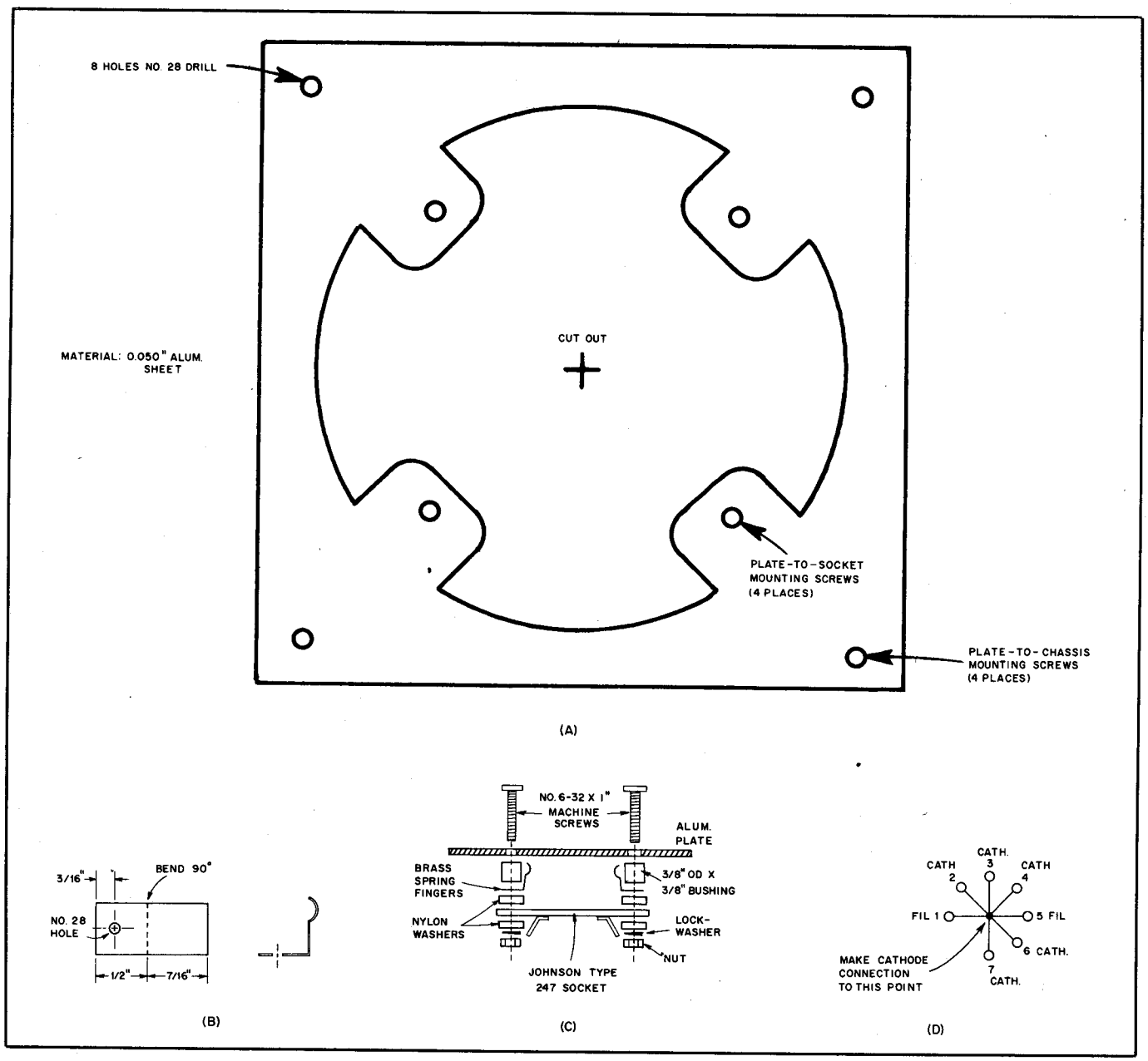


Fig. 53 — Details of the homemade socket for the 8877 tube. All hardware is no. 6-32. A full-size template for the aluminum plate is shown at A. Connection to the grid is made through four spring fingers made from spring brass or copper. Details of these clips are shown at B. Assembly of the socket is shown at C. Assemble as follows. Insert four 1-inch no. 6-32 machine screws through the plate. Slip a 3/8-inch by 3/8-inch-OD aluminum bushing over each screw. Place a spring finger on each screw, followed by a nylon washer. Slide the Johnson 247 socket onto the screws, and secure each screw with a nylon washer, metal lock washer and nut. Align the spring fingers for good contact with the grid ring and tighten. Connections to the bottom of the socket are shown at D.

the meters and is adjustable from the top. Liberal use of terminal strips simplifies wiring. There is plenty of room, and wiring is not critical at all, except that the input network should be mounted near the tube socket.

Testing and Tune Up

Connect the amplifier output to a dummy load through a wattmeter capable of reading 1500 W. Connect an HF transmitter capable of supplying at least 60 W to the amplifier input through an SWR/wattmeter. Connect a high-voltage supply, preferably with a variable autotransformer on the ac line to make the B+ continuously variable, to J2 and J3. The power supply should be able to deliver approximately 2500 V at 1 A. Be careful: The high voltage in this amplifier can be lethal!

Apply 117-V ac to the RF deck and operate the blower switch. The blower should come on, and the blower indicator lamp will light. You should feel air exhausting through the tube cooler.

Operate the filament switch. After a short delay, the filament indicator will light showing that the inrush protection circuit has cycled. Operate the reset switch, and the indicator lamp will light showing the amplifier is in the "go" condition. EIMAC recommends that the 8877 filaments be on for three minutes before high voltage is applied. No delay circuit for plate voltage control has been provided here, so wait three minutes before turning on the plate supply.

Apply plate voltage gradually. Do not apply drive yet. Watch and listen for any

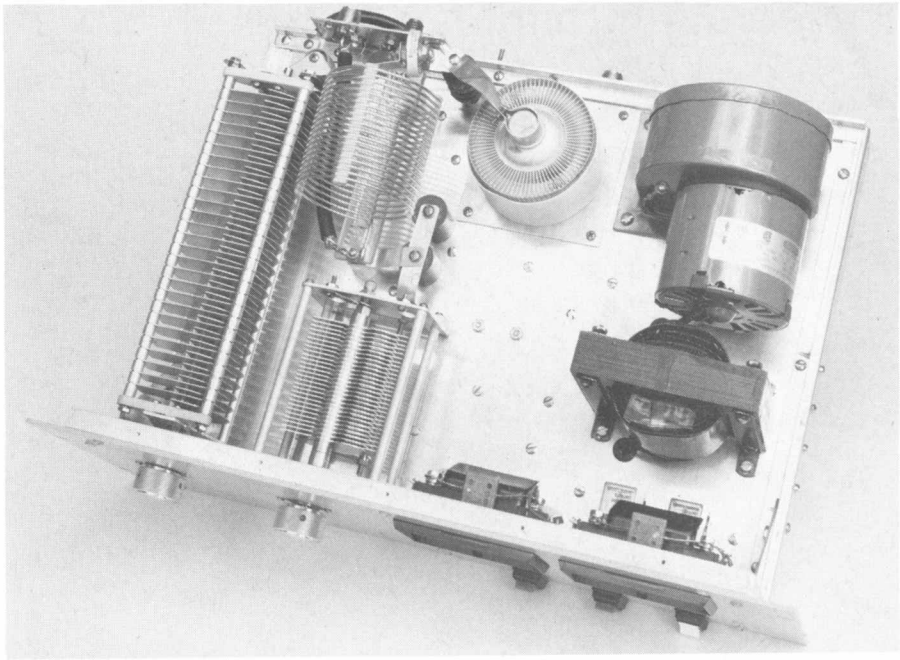


Fig. 54 — Top-side view of the 160-meter amplifier chassis.

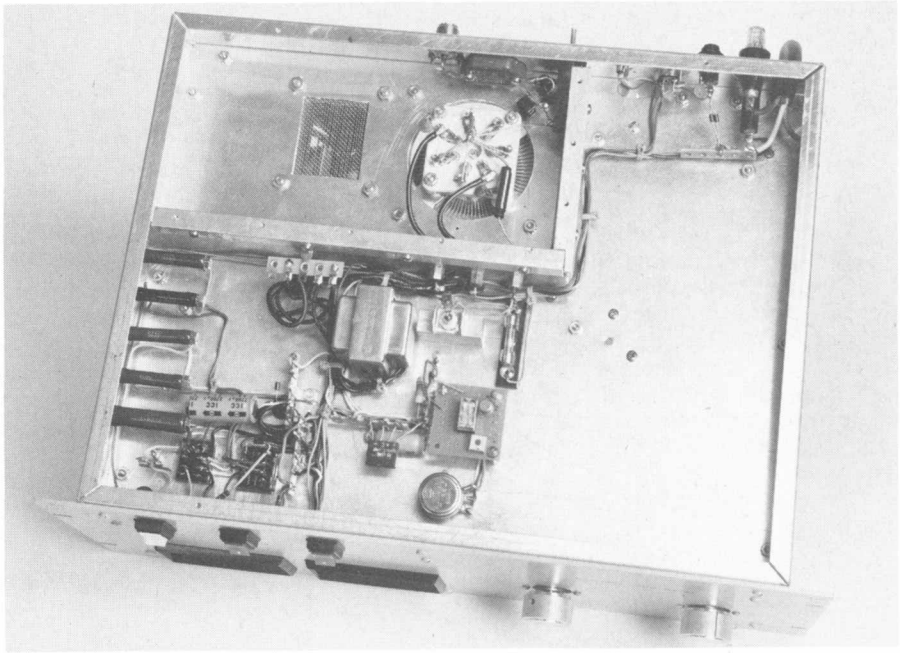


Fig. 55 — View of the underside of the 160-meter amplifier chassis.

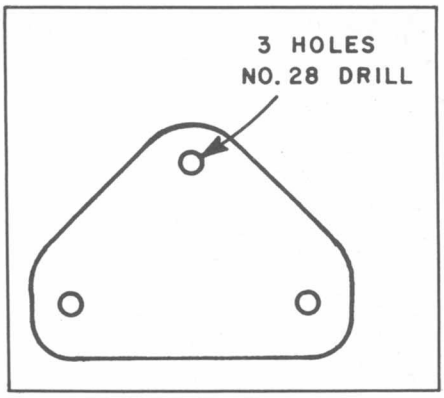


Fig. 56 — Full-size template of the plate used to connect the three doorknob capacitors that make up C17 to C18.

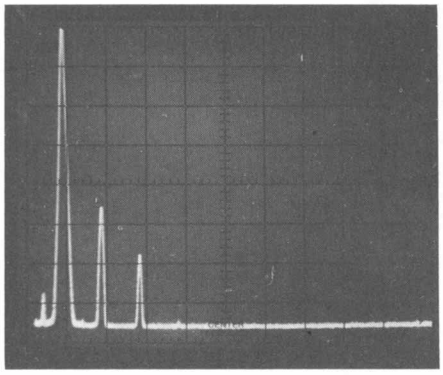


Fig. 57 — Spectral output of the 160-meter amplifier. Power output is 1500 W on 1.8 MHz. Each vertical division is 10 dB and each horizontal division is 2 MHz. All harmonics and spurious emissions are greater than 44 dB down. This amplifier complies with current FCC spectral-purity requirements.

signs of arcing as you bring the plate voltage up to full operating potential. There should be no indication on M1 or M2. If all appears to be okay, lower the plate voltage to about 1000 V and apply about 10-W drive. Adjust L1 for lowest input SWR.

Increase drive and adjust the pi network for maximum output. Most likely the grid overcurrent trip circuit will operate, placing the amplifier in STANDBY. Decrease the sensitivity by adjusting R4. This control is near high-voltage points, so take care and use an insulated screwdriver. Adjust this potentiometer so the grid protection circuit trips at 60 to 70 mA.

Apply full plate voltage and gradually increase drive. Adjust C18 and C19 for maximum output. These controls are somewhat interactive. Do not exceed 1 ampere of plate current. Recheck the input SWR when you reach full output power. Some additional adjustment of L1 may be necessary. Output power should be 1500 W with a plate voltage of approximately 2600 at 1 ampere and 60-W drive. Fig. 57 shows the amplifier spectral output.

A Legal-Limit Amplifier for 160 through 10 Meters

The amplifier described here is an update of the 1500-W output legal-limit amplifier described in the 1985 and 1986 *ARRL Handbooks*. It uses the EIMAC 8877 (3CX1500A7) high-mu triode in grounded-grid service. The 8877 will easily deliver 1500-W RF output with the drive levels afforded by most 100-W-class transceivers. Operating at 1500-W output, tube dissipation is well within the manufacturer's specification.

Shown in Figs. 58 through 68, this amplifier covers 160 through 10 meters, not including the WARC bands. Operation on the 24-MHz WARC band is possible with the band switch in the 28-MHz position, but the input SWR will be a little higher than on the other bands. Many of the components used were purchased at flea markets and from mail-order dealers. The names and addresses of the parts suppliers are detailed at the end of Chapter 35. Amplifier parts are expensive. The builder is encouraged to substitute components from surplus dealers or flea markets where possible if cost is a problem. Be sure, however, to use only components with adequate ratings. The dc and RF power levels found in this project are capable of destroying parts with insufficient ratings.

Dick Stevens, W1QWJ, designed and built this project. The power supply and RF deck are built on separate chassis because of the size and weight of the power supply. Standard 19-inch rack panels are used for the front panels, so both pieces may be rack mounted if desired.

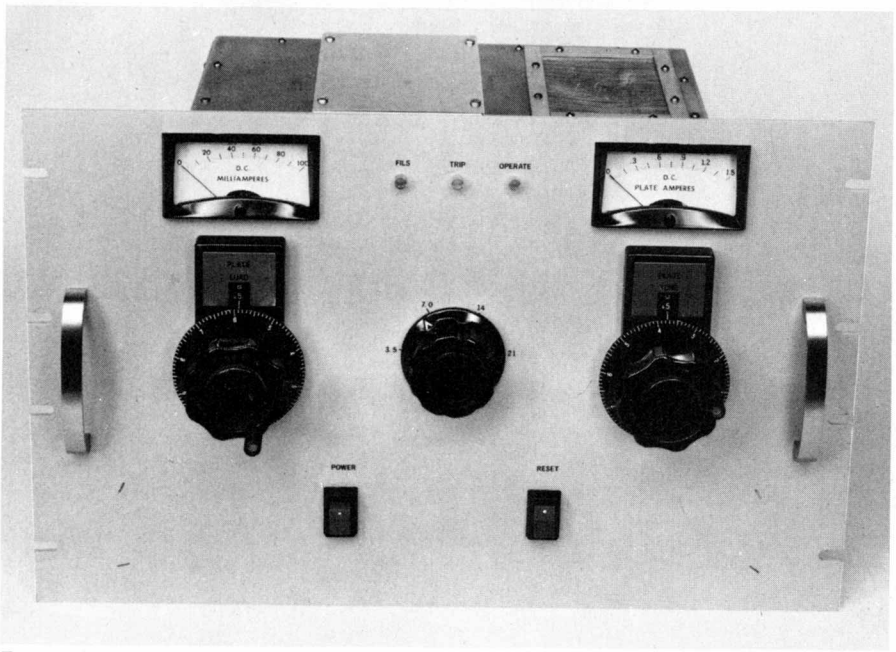


Fig. 58 — The 8877 HF amplifier uses a standard rack-type front panel. The tuning and loading capacitors are controlled by venier drives with turns counters. Once the settings for each band are determined, they can be recorded for quick band changes.

Power Supply

The high-voltage power supply delivers 1 A continuously at user-selectable voltages of 2.5, 3 or 3.5 kV. During normal operation, only the 3-kV position is used, but a lower level is available for tuneup, and a higher level is available if line sag is a problem. Circuits are provided for protection, automatic start and PTT line control. Fig. 59 is the power-supply schematic diagram, and the unit is pictured in Figs. 60 and 61.

Circuit Details

The secondary side of the power supply is conventional. T1 is a Hipersil transformer with a 234-V primary and secondary taps at 1770, 2125 and 2475 V. S3 is a high-voltage switch with large contacts and ceramic insulation used to select among the taps. The 234-V primary and full-value secondary contribute to good voltage regulation. D2 through D5 are 14-kV, 1-A rectifiers connected in a full-wave bridge. C2 is a surplus 53-μF, 3.5-kV oil-filled capacitor. If the builder cannot locate one of these units, a suitable replacement should be at least 25 μF at a similar voltage rating. R4, the 200-kΩ bleeder resistor, is made up of eight 25-kΩ, 25-W units connected in series.

A high-voltage meter (M1) is included in the supply. The value of R_M, the multiplier resistor, will depend on the value of the basic meter movement. See Chapter 25 for information on meter multipliers and shunts. The B– lead floats above chassis ground. R3 is included to keep the B– near ground potential. The floating B– allows plate current to be metered in the negative lead for safety. C4 and C5 are bypass capacitors.

Power enters the supply from the 234-V line through a 20-A, 2-pole circuit breaker. DS1 will light when the circuit breaker is closed. With S1 in AUTOMATIC and S2 in START, a 24-V signal at J4 from the amplifier control circuitry will energize K1. K1A closes, energizing K2. DS2 lights. K2A and K2B apply reduced primary voltage to T1 through R2. After a second or so, C1 charges and energizes K3. K3A closes, shorting across R2, to apply full primary voltage to T1. This circuit protects D2-D5 from damage by effectively limiting inrush current through the rectifiers while C2 charges. R1 adjusts the charging time for C1. DS3 lights, signaling that the power supply is ready for service. An additional protective feature is that K1B is in the exciter PTT line to prevent keying the amplifier without high voltage present. Note that the supply can be activated manually (not by the amplifier control circuit) by placing S1 in the OFF position and using S2 to turn the supply on and off. PTT line protection is lost in the manual mode, however.

J1 is a grounded, polarized 117-V ac receptacle used to provide power to the RF deck. Correct 117-V ac wiring must be used here. The ground (green) wire is connected to the chassis ground. The neutral (white) wire is connected to the 234-V line neutral. The hot side (black) is connected to one side of the 234-V line. Likewise, standard wiring must be used in the RF deck.

J1 and J2 are Millen connectors rated at 7 kV. Test prod wire (5-kV insulation) is used for the B+ and B– runs to the RF deck. A braid ground strap bonds the power supply and RF deck chassis together for added protection.

Construction

The power supply is built behind a standard 12½-inch-high, 19-inch-wide rack panel. It is designed to fit inside a Bud Prestige series cabinet. T1 needs a good base to support the weight, so the bottom plate is made from a piece of ¼-inch-thick aluminum plate that is approximately 14 inches square. The size and shape of the power supply enclosure will depend on the actual components used. Be sure that it is sturdy, and allow sufficient room for air to circulate.

T1 and C2 are bolted to the bottom plate. The rectifiers, control relays and other parts mount on a shelf above C2. The eight 25-W resistors that make up the bleeder are mounted to two vertical strips of phenolic stock.

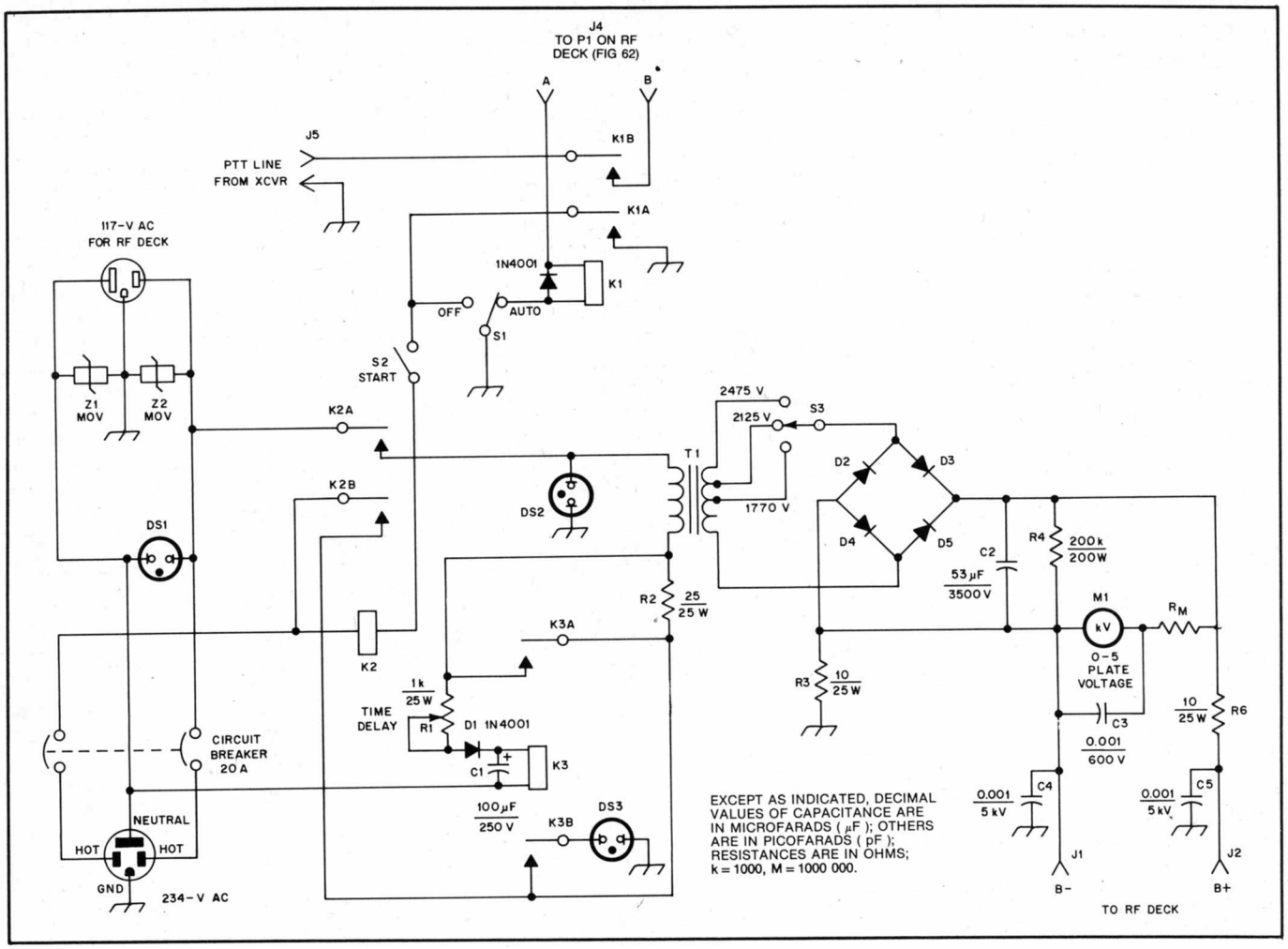


Fig. 59 — Schematic diagram of the high-voltage power supply. Capacitors are disc ceramic unless noted. Possible parts sources are listed in parentheses. See Chapter 35 for the addresses of the parts suppliers.

C2 — Oil-filled capacitor, 53 μF, 3.5 kV (Electronic Emporium cat. no. 4W308T or equiv.).
D2-D5 — Rectifier, 14 kV, 1 A (K2AW's Silicon Alley HV-14 or equiv.).
DS1-DS5 — Neon pilot lamp, 120 V, with built-in dropping resistor (Radio Shack).
J1, J2 — High-voltage connector (Millen 37001 or equiv.).
J3 — Chassis-mount three-wire 117-V ac socket.
J4 — Two-conductor Jones socket.
J5 — Chassis-mount phono jack.
K1 — 4PDT relay, 24-V dc coil, 2-A contacts. (Potter & Brumfield KH4703-1 or equiv.).
K2, K3 — DPST relay, 120-V ac coil, 20-A contacts. (Potter & Brumfield PRD7AYO or equiv.).
M1 — 0 to 50 μA meter with suitable multiplier resistor (R_M). See text.
R_M — Meter multiplier resistor. Exact value will depend on meter movement used. See text and Chapter 35 for information on meter multipliers.
R1 — Adjustable resistor, slider type, 1-kΩ, 25 W.
R4 — 200-kΩ, 200-W bleeder made from eight 25-kΩ, 25-W resistors in series (see text).
S1 — SPDT switch, 117-V, 3-A contacts.
S2 — SPST switch, 117-V, 3-A contacts.
S3 — High-voltage switch (see text).
T1 — Power transformer; 234-V primary, secondary taps at 1770, 2125 and 2575 V (Peter W. Dahl Co. no. PT-2475 or equiv.).
Z1, Z2 — 130-V metal-oxide varistor (Radio Shack).

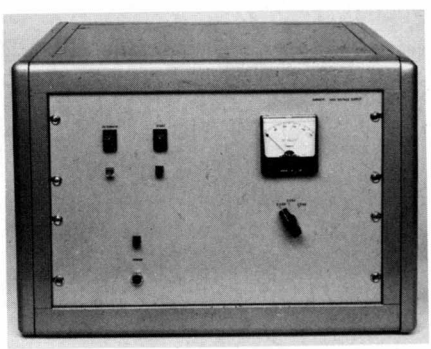


Fig. 60 — Front panel view of the 8877 amplifier high-voltage supply. It is built on a 12½-inch high rack panel and mounted in a Bud Prestige cabinet. Output voltages of 2.5, 3 and 3.5 kV are switch-selectable from the front panel.

RF Deck

The RF deck houses the 8877 and associated RF circuitry as well as the amplifier-control circuit board. This amplifier uses a tuned input circuit and a pi-L output circuit. The filament transformer (T1) and antenna relay (K6) are built in. Cooling is provided by blower B1. Fig. 62 is a schematic diagram of the control circuitry, and Fig. 63 shows the RF circuitry.

Control Circuits and Metering

The control circuits are somewhat involved and are designed to protect the expensive 8877 tube from excessive fila-

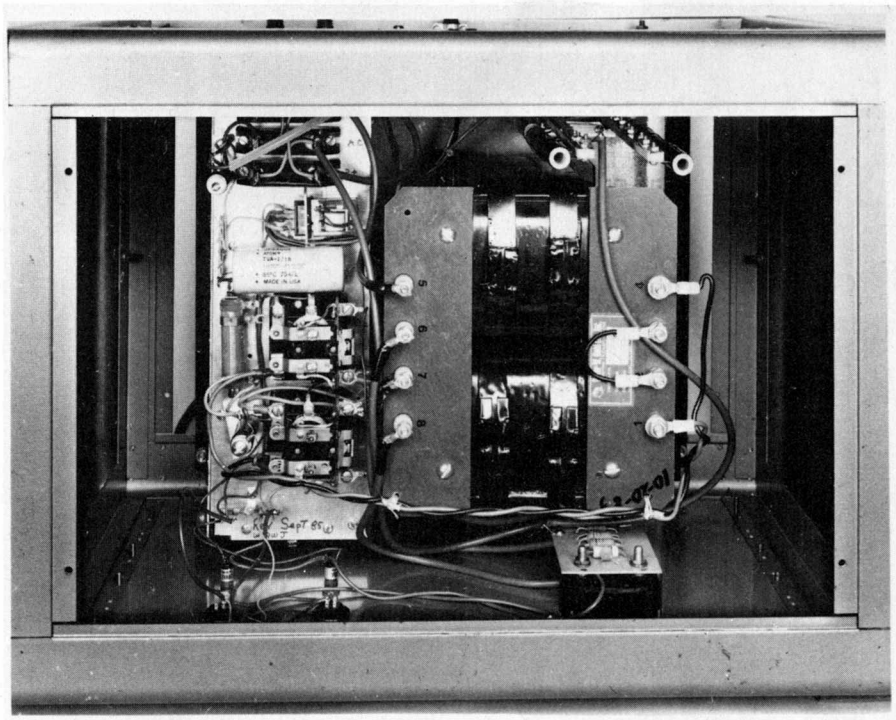


Fig. 61 — Interior of the high-voltage power supply cabinet.

ment inrush current, excessive grid current, and application of drive in the absence of plate voltage. A three-minute delay circuit prevents keying the amplifier until the tube gets up to operating temperature, and another time-delay circuit keeps the blower running for a short while after power is removed.

When S1 of Fig. 62 (POWER) is closed, several things happen. First, 117-V ac is applied through R2 to the primary of filament transformer T1. R2 limits inrush current and is in the line until C2 charges, energizing K2. K2A shorts across R2, applying full primary voltage to T1. K2B lights the FILS LED. Note that T1 has several primary taps to allow adjustment of the filament voltage (measured at the socket) to 5.0 V, ±0.25 V, as specified by the tube manufacturer. At the same time filament power is applied, blower B1 starts and time-delay relay K1 starts to heat. K1A does nothing at this time. When power is turned off, however, K1A will stay closed for several minutes to run the blower and cool the tube after filament voltage is removed. K1 does not control the blower directly, but rather does so through K8, a relay with contacts heavy enough to handle the current needed by the blower motor.

S1 also starts K3, a three-minute time-delay relay. When K3 energizes, the OPERATE LED lights. Finally, S1 applies primary voltage to T2 of the 24-V dc control-relay supply. When S2, RESET, is closed, 24 V is applied to various points in the control circuit. A 24-V signal is sent through relay contacts K4B and K3A to energize K1 in the high-voltage power supply. K3A also allows 24 V to reach K5, the PTT relay, so that the amplifier may be keyed from the PTT line. Note that since K3A is in the line to the HV-supply control relay and the PTT relay, the HV supply cannot be turned on and the PTT line cannot be keyed until after the three-minute warmup period.

The transceiver PTT control connects to the HV power supply, and K1B in the power supply activates K5 in the RF deck to prevent keying the amplifier in the absence of B+. K5A applies operating bias to the 8877, and K5B operates the antenna TR relays (K6, K7). K6 has a slight time delay, provided by C5. This feature assures that K7 will close before K6 to prevent hot switching.

Protection from excessive grid current is provided by Q1 and associated components. When the grid current exceeds a certain amount (set to approximately 70 mA by R5), Q1 fires and operates K4. K4C lights the TRIP LED. K4B opens, shutting off the HV supply and opening the PTT circuitry to protect the tube. To reset the amplifier, switch S2 off and then on again and everything will restart automatically. S2 can also be used to place the amplifier in standby if operation with the transceiver only is desired.

M1 and M2 of Fig. 63 monitor grid current and plate current. Plate current is monitored in the B− lead, rather than in the B+ lead, for safety. A pair of back-to-back diodes and 0.01-μF capacitors protect the meters from transients and RF voltages.

Input Circuitry

The RF input appears at J1 of Fig. 63. If the amplifier is turned off or bypassed by S2 of the control circuit, the input signal is routed directly to the output connector, J2. When the amplifier is in operation, the input signal goes to the tuned input circuitry and then to the 8877 cathode. Although the 8877 input impedance is close to 50 ohms and RF drive could be connected directly to the 8877 cathode, the tuned input is used for improved linearity and lower drive requirements.

There is a separate pi network (C1, L1, C2) for each band. S1 selects the appropriate network for the band in use. The input networks were designed with a Q of approximately 2 to be broadly resonant on each band. For clarity, only one pi network is shown in Fig. 63. Table 1 presents the complete input network data.

The coil (L1) for each band is wound on a 3/8-inch slug-tuned form. The slugs were purchased from a surplus dealer, but any 3/8-inch slug-tuned form with a red core should work. Table 1 gives both calculated capacitor values and the real-world values used in this amplifier.

Output Circuitry

B+ enters the RF deck through J3 and is routed through RFC2 and RFC3. The B+ line is bypassed by C8 and C9. C7 is a dc blocking capacitor that keeps dc voltages out of the tank circuit and off the feed

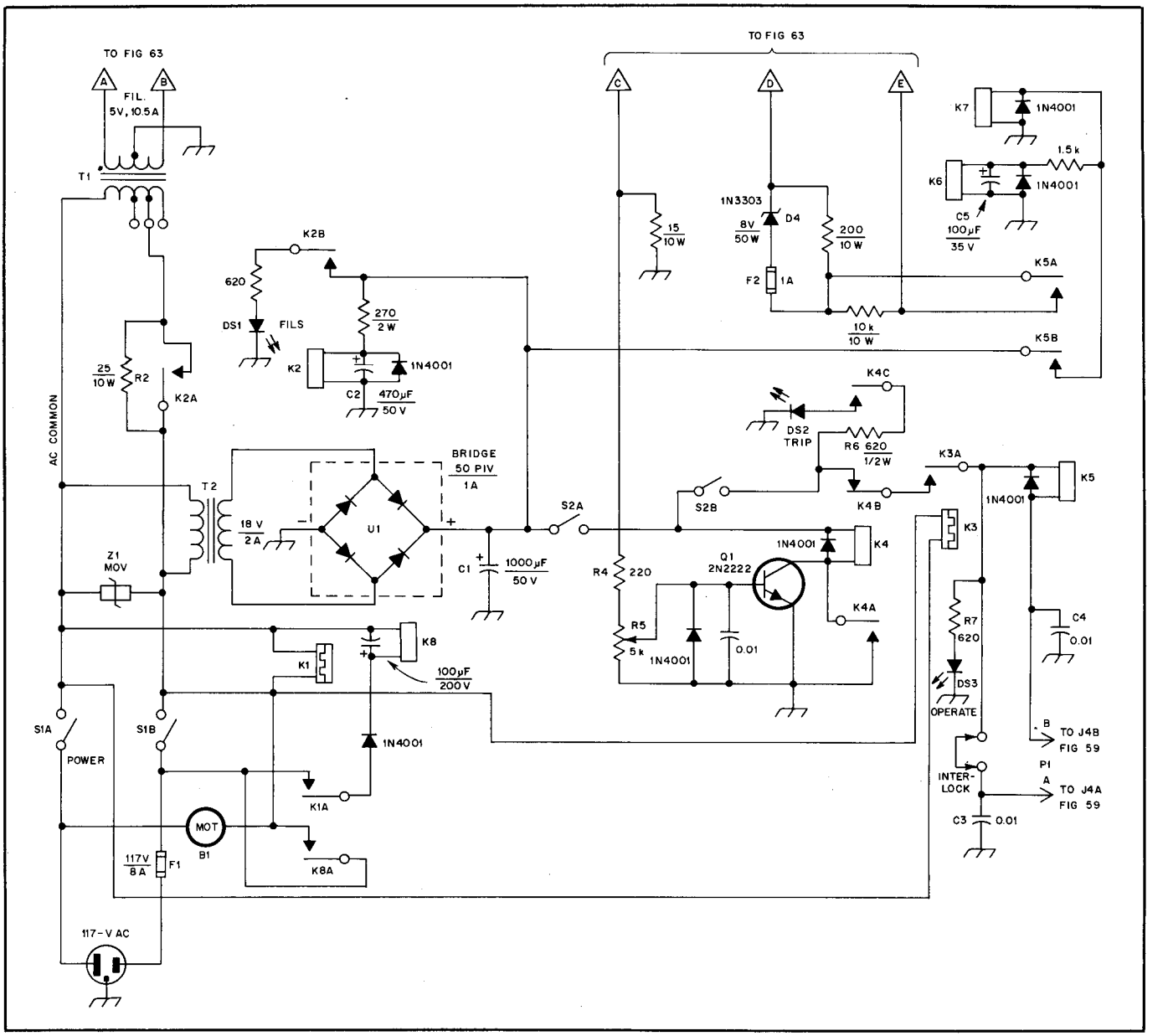


Fig. 62 — Schematic diagram of the 8877 amplifier control circuitry. Resistors are ¼-W types unless noted. Capacitors are disc-ceramic types unless noted. Capacitors marked with polarity are electrolytic. See Chapter 35 for the addresses of the parts suppliers.

B1—Blower, 54 CFM (Dayton 4C012A or equiv.).
DS1-DS3—LED.
D4—Stud-mount Zener diode, 8 V, 50 W (1N3303 or equiv.).
K1—Time-delay relay with a 2-3 minute delay on release, 115-V ac coil (Amperite 115NO69 or equiv.).
K2—DPDT relay, 12-V dc coil with 120-V, 10-A contacts (Radio Shack).
K3—Time-delay relay with a 3-minute delay on operate, 115-V ac coil (Amperite 115NO180 or equiv.).
K4, K5—4PDT relay, 24-V dc coil with 2-A contacts (Potter & Brumfield KH4703-1 or equiv.).
K6, K7—Dow Key Model 60 coaxial antenna relays with 24-V dc coils.
K8—DPDT relay, 120-V ac coil with 125-V ac, 10-A contacts (Radio Shack).
T1—Filament transformer. Primary: 120-V with taps for ±4% and ±8%; secondary: 5 V, 10.5 A (Avatar Magnetics AV-454 or equiv.).
P1—Two-conductor Jones plug to match J4 in the HV power supply (Fig. 59).
T2—Power transformer. Primary: 117-V; secondary: 18 V, 2 A.
U1—Bridge rectifier module, 50 PIV, 1 A (Radio Shack).
Z1—130-V metal-oxide varistor (Radio Shack).

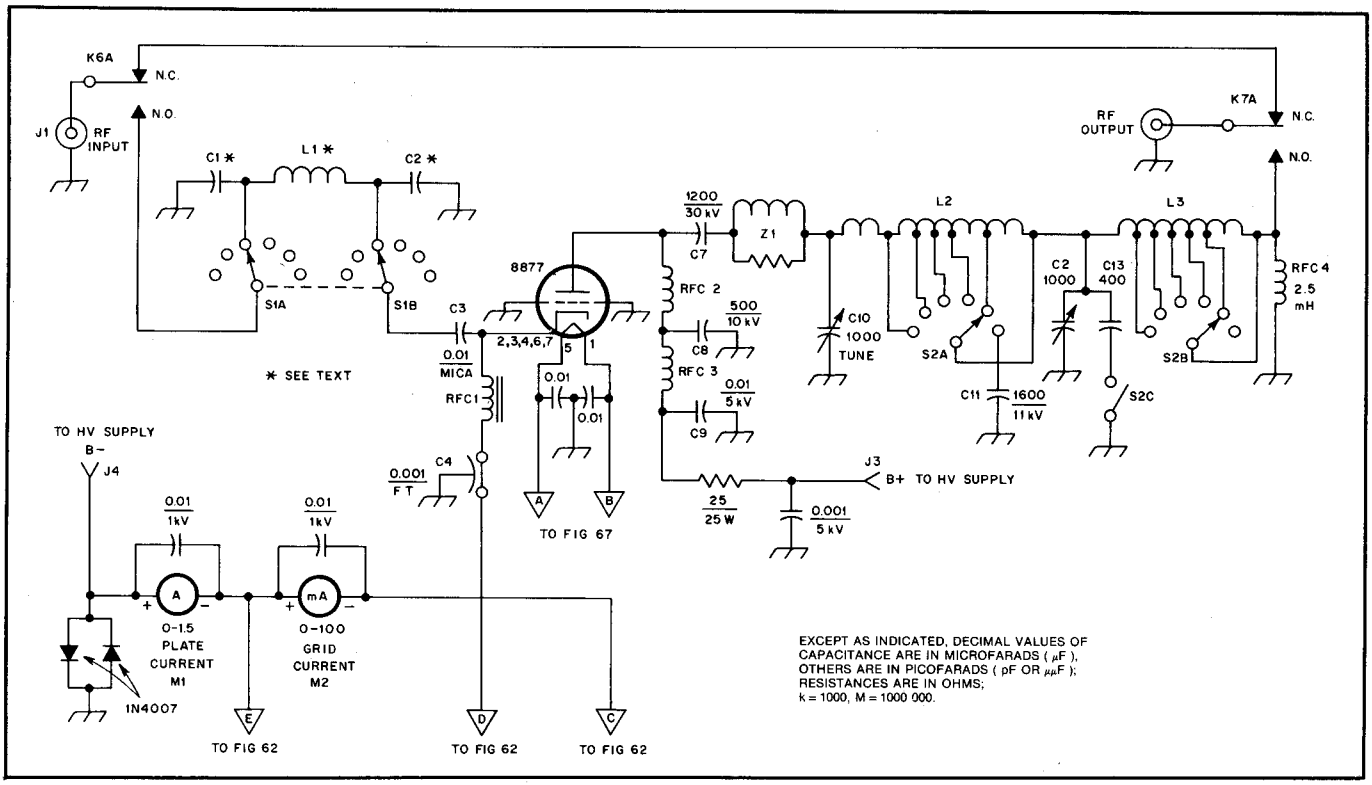


Fig. 63 — Schematic diagram of the 8877 amplifier RF deck. Resistors are ¼-W types unless noted. Capacitors are disc-ceramic types unless noted. Capacitors marked with polarity are electrolytic. See Chapter 35 for the addresses of the parts suppliers.

C1, C2—See Table 1.
C7—1200-pF, 30-kV RF-type doorknob capacitor (Electronic Emporium).
C10—1000-pF, 5-kV vacuum variable capacitor (Jennings UCSL 1000-5 or equiv.).
C11—Two 800-pF, 5-kV doorknob capacitors in parallel.
C12—1000-pF, 1.5-kV air variable (Cardwell 154-30 or equiv., avail. from RadioKit).
C13—400-pF, 5-kV doorknob capacitor.
J1, J2—Female UHF connector (in this case, part of K6 and K7).
J3, J4—High-voltage connector (Millen 37001 or equiv.).
K6, K7—See Fig. 62.
L1—See Table 1.
L2, L3—See Fig. 64.
RFC1—50 μH; 39T no. 24 enam. wire close wound on a ¼- inch powdered iron core.
RFC2—No. 24 enam. close wound on a 1-inch Teflon form. The form is 5 inches long; the winding is 4 inches long. Measured inductance is 195 μH.
RFC3—8.2 μH (Ohmite Z50 or equiv.).
RFC4—2.5 mH (Millen 4537 or equiv.).
S1—Single wafer, 2-pole, 6-position ceramic rotary switch with indexing to match S2.
S2—Six position, two section, high-power ceramic RF switch with non-shorting contacts and 60-degree indexing (Model 86, avail. from Radio Switch Corp., Rt. 79, Marlboro, NJ 07746). Section S2C is a homemade addition. See Fig. 68.
Z1—Parasitic suppressor. Made from 2T of ½-inch wide copper strap, ½-inch ID. Shunt the strap with two 100-Ω, 2-W carbon-composition resistors in parallel.

Table 1
Input Coil Data

Band	*L1 (μH) (Calculated)*	*L1 Winding Information*†	*C14, C15 (pF) (Calculated)*	*C14, C15 (pF) (Values Used)*
160	4.2	27T no. 24	1640	1120 + 560 = 1680
80	2.07	16T no. 22	820	820
40	1.18	9T no. 20	430	210 + 210 = 420
20	0.59	7T no. 20	220	210
15	0.39	5T no. 20	150	150
10	0.30	4T no. 20	100	100

†All coils wound on 3/8-in-diameter form; slug-tuned with red core. Available from Electronic Emporium, part number PLS5-B-2.

line and antenna. Should C22 short, placing dangerous voltage on the output connector, RFC4 will short the B+ line to ground and blow the power-supply circuit breaker.

This amplifier uses a pi-L tank circuit for better suppression of harmonic energy. To get a better Q and improved efficiency on 10 and 160 meters, a 1000-pF vacuum-variable capacitor was chosen for C10 (TUNE). C12 (LOAD), a 1000-pF air variable, does not have enough capacitance for operation on 160 and 80 meters. A spare contact on S2A switches C11 into the circuit for 160-meter operation, while S2C switches C13 into the circuit for 80-meter operation.

L2 is made from a section of ¼-inch copper tubing for 10 meters and a section of B&W Pi Dux stock for the other bands. The L coil, L3, is also made from a small section of Pi Dux stock. S2 switches the taps for use on the various bands. Fig. 64 is a detailed diagram of the tank coil connections.

Construction

The completed RF deck is shown in Figs. 65 and 66. The main support for the components is a standard 4- × 17- × 10-inch (HWD) chassis (Bud AC-427). Like the power supply, the chassis is mounted

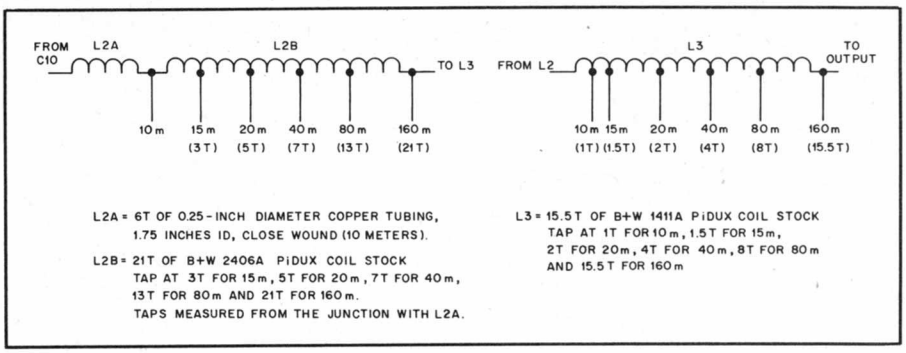

FROM C10
L2A
L2B
TO L3
10m
15m (3T)
20m (5T)
40m (7T)
80m (13T)
160m (21T)
L2A = 6T OF 0.25-INCH DIAMETER COPPER TUBING, 1.75 INCHES ID, CLOSE WOUND (10 METERS).
L2B = 21T OF B+W 2406A PiDUX COIL STOCK TAP AT 3T FOR 15m, 5T FOR 20m, 7T FOR 40m, 13T FOR 80m AND 21T FOR 160m. TAPS MEASURED FROM THE JUNCTION WITH L2A.
FROM L2
L3
TO OUTPUT
10m (1T)
15m (1.5T)
20m (2T)
40m (4T)
80m (8T)
160m (15.5T)
L3 = 15.5T OF B+W 1411A PiDUX COIL STOCK TAP AT 1T FOR 10m, 1.5T FOR 15m, 2T FOR 20m, 4T FOR 40m, 8T FOR 80m AND 15.5T FOR 160m

Fig. 64 — Details of the pi-L coils, L2 and L3 of Fig. 63.

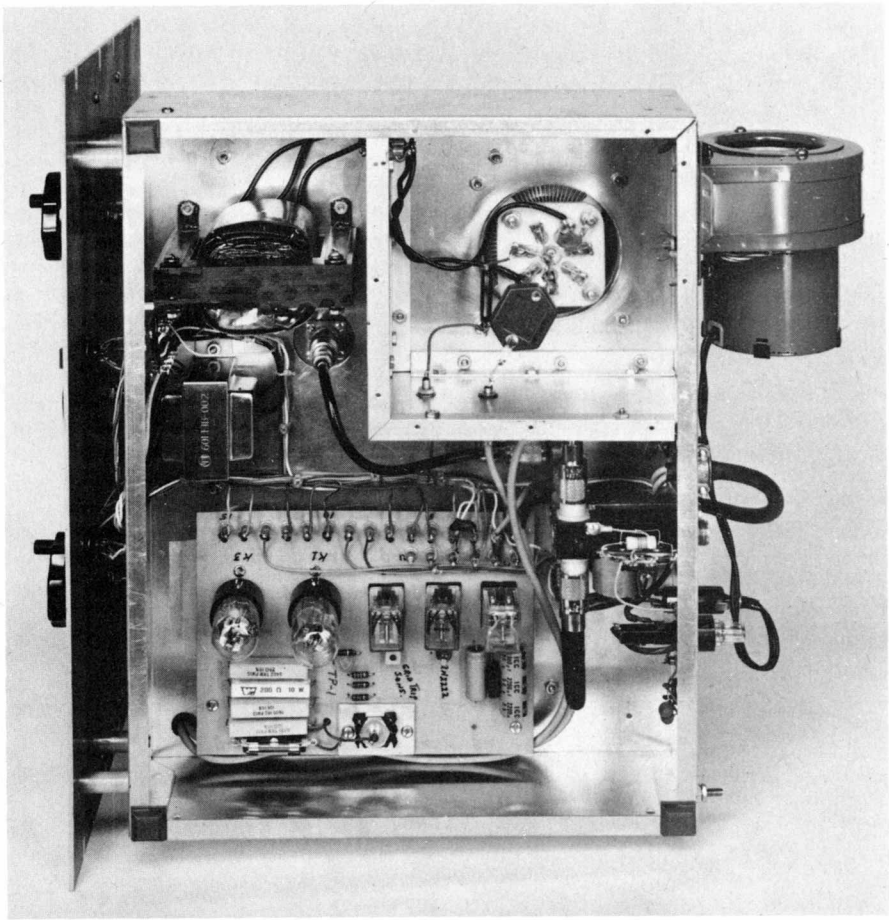


Fig. 65 — Underside of the 8877 amplifier chassis.

to a 19-inch-wide, 12½-inch-high rack panel. For RF shielding, sidewalls 4¾ inches high are mounted to the chassis with aluminum angle stock. A top cover bolts to aluminum angle stock that is connected to the sidewalls. Similar aluminum-sheet-and-angle-stock construction is used to enclose the tube socket underneath the chassis.

A separate enclosure that is bolted to the amplifier top cover houses the input circuitry. This enclosure is positioned so that its band switch is directly above the main band switch in the output network. A simple chain drive from the main band switch makes both input and output switches turn in unison from a single front-panel control. The sprockets (part no. RCS-12) and chain (RCX-25) are available from Small Parts, Inc. See the parts suppliers list in Chapter 35. Align the chain drive with both switches in the 10-meter position. Leave some slack in the chain to allow the detents in both switches to function effectively.

The underside of the chassis is shown in Fig. 65. A single circuit board in the lower half of the photo contains the bias and control circuitry. The antenna relays are mounted to the rear chassis wall, to the right of the control circuitry. The filament and control circuit transformers are mounted at the top left of the photo, near the front panel, and the tube socket is to the right of the transformers. A Dayton blower pressurizes the enclosed cathode compartment, and air exits through the tube anode cooler. A Teflon chimney directs the exhaust air.

The tube socket is homemade from a Johnson 247 ceramic socket and miscellaneous hardware. Complete details for fabrication of this socket are shown earlier in this chapter, associated with a 160-meter 8877 amplifier. The recommended EIMAC socket is part number SK-2200.

The relative positions of the output-network components is shown in Fig. 66. The tuning capacitor is mounted close to the tube, and the loading capacitor is on the other side of the chassis. Both of these capacitors use Groth turns-counter dials with vernier drives for smooth tuning. These drives were purchased from Robert H. Bauman Sales, P.O. Box 122, Itasca, IL 60143.

The band switch is in the center of the chassis. S2C, to switch in additional loading capacitance for 80 meters, is a homemade addition to the band switch. It consists of two Barker and Williamson high-power switch contacts (available from B&W or RadioKit — see Chapter 35) and a wafer made from a piece of double-sided PC-board material. See Fig. 68. S2C is attached to the main band switch shaft.

The pi coil, L2, may be seen to the left of the 8877. The two coil pieces are supported by a rectangular piece of glass-epoxy circuit board material with all copper removed. The coil assembly is mounted above the chassis with ceramic standoffs. The L coil is mounted with a similar arrangement to the left of the band switch and perpendicular to the pi coil. The two coils must be mounted at right angles to prevent undesired coupling. All plate circuit connections are made with copper straps.

In this amplifier, it was necessary to provide a ½-inch wide ground strap between the tuning and loading capacitors to prevent ground-loop currents. Connect the frame of the loading capacitor to the lead-screw mechanism of the vacuum variable. Do not ground this strap to the chassis.

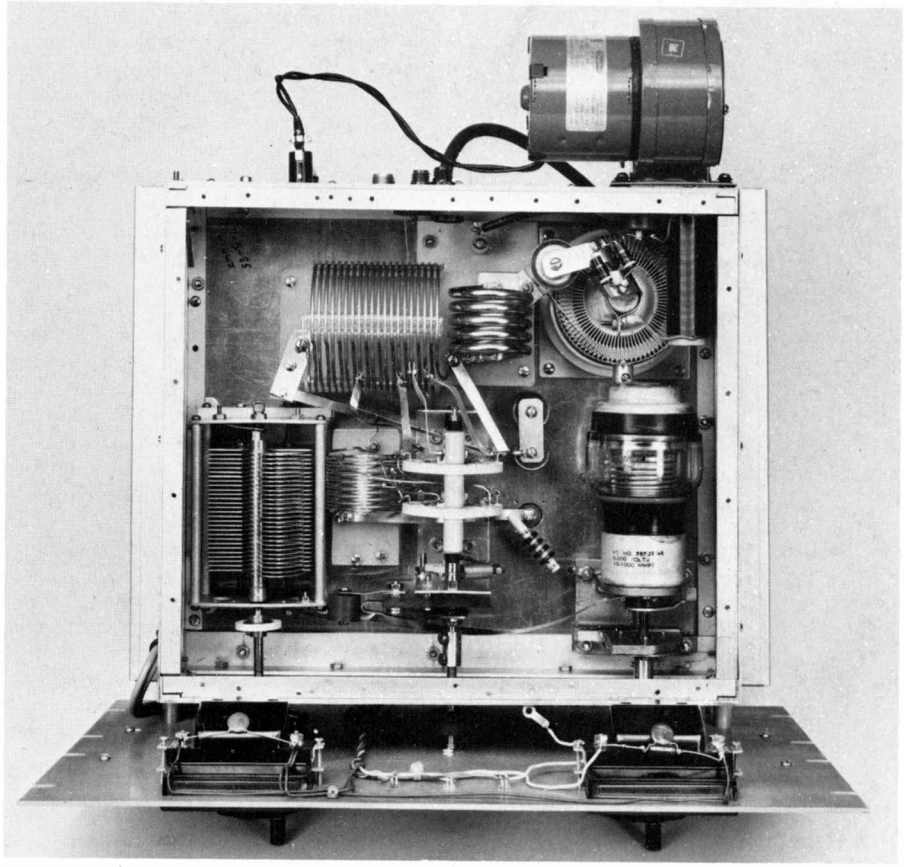


Fig. 66 — Interior of the 8877 amplifier RF deck. The input compartment, which was attached to the top cover, has been removed. The chain-drive sprocket on the main band-switch shaft is visible between the chassis and the front panel.

Tuneup and Operation

Check the high-voltage power supply for proper operation before connecting it to the RF deck. Check all circuit paths in the B+ supply and RF deck for possible short circuits. Verify the operation of all control circuitry with the high-voltage off and with the tube removed from the socket. If everything works, apply power to the filament transformer, blower and control circuitry, and measure the filament voltage at the tube socket. If all is well, remove power from the RF deck and install the covers. Connect the high-voltage supply. Connect an exciter capable of delivering about 100 W to the input through a wattmeter and connect the amplifier output to a suitable dummy load through a second wattmeter.

Place the power-supply switches in AUTOMATIC and START. Close the RESET switch on the RF deck and turn the POWER switch on. The blower will start and filament power will be applied. The FILS lamp will light. After three minutes, K3 will close and the high-voltage supply will turn on. Press the transceiver PTT switch. M2 should indicate about 150 mA resting plate current.

Apply about 10 to 20 W of drive and adjust the TUNE and LOAD controls until the grid-current meter reads about 70 mA. Adjust R5 until the grid-trip circuit functions. Reset the circuit and verify that the grid-trip circuit functions at about 70 to 80 mA.

Apply about 10-W drive and adjust the slugs of the coils in the input pi networks for lowest SWR at the center of each band. Adjust the TUNE and LOAD controls for maximum output. Tuning of a pi-L circuit is similar to that for a conventional pi circuit, except that the setting of the LOAD capacitor is much more critical. Gradually increase drive until the power output reaches 1500 W. Recheck the input SWR on each band with the amplifier running at full output.

Table 2 shows the operating parameters for this amplifier as measured in the ARRL lab. Fig. 67 shows the exceptionally clean spectral output from the pi-L network.

Table 2

8877 Amplifier Operating Characteristics

Band	*Power Output (W)*	*Plate Voltage (V)*	*Plate Current (mA)*	*Grid Current (mA)*	*Drive Power (W)*	*Input SWR*
160	1500	2700	1000	30	65	1.1:1
80	1500	2800	900	35	65	1.2:1
40	1500	2800	900	40	65	1.1:1
20	1500	2800	1000	40	65	1.2:1
15	1500	2800	1000	45	65	1.2:1
12	1500	2800	1000	50	65	1.5:1
10	1500	2800	980	50	65	1.4:1

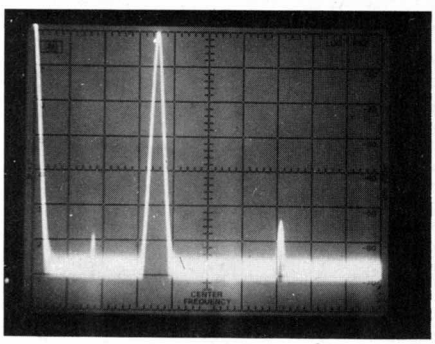
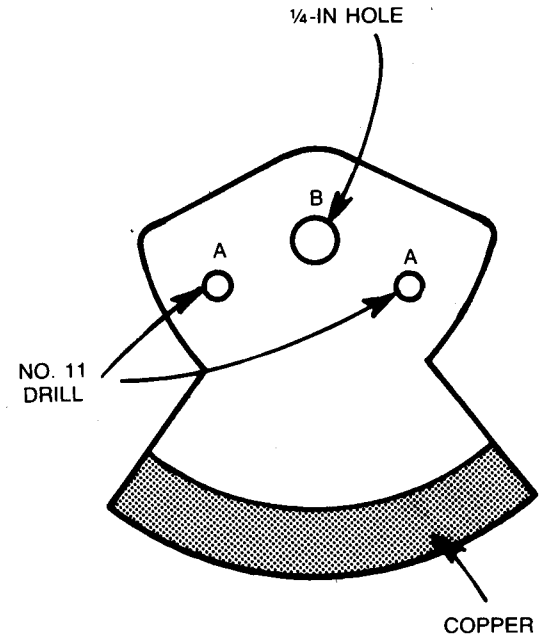
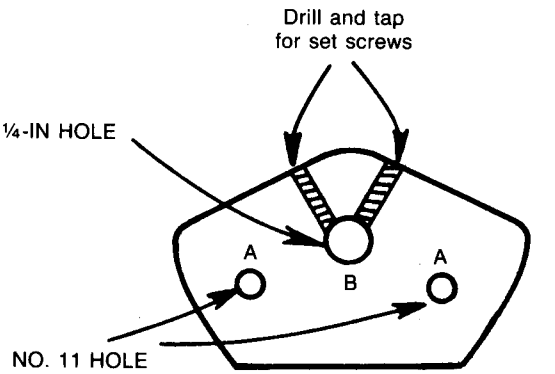


Fig. 67 — Worst-case spectral photograph of the 8877 amplifier. Power output is 1500 W on 3.5 MHz. Each vertical division is 10 dB, and each horizontal division is 1 MHz. All harmonics and spurious emissions are at least 54 dB down. This amplifier complies with current FCC spectral-purity requirements.

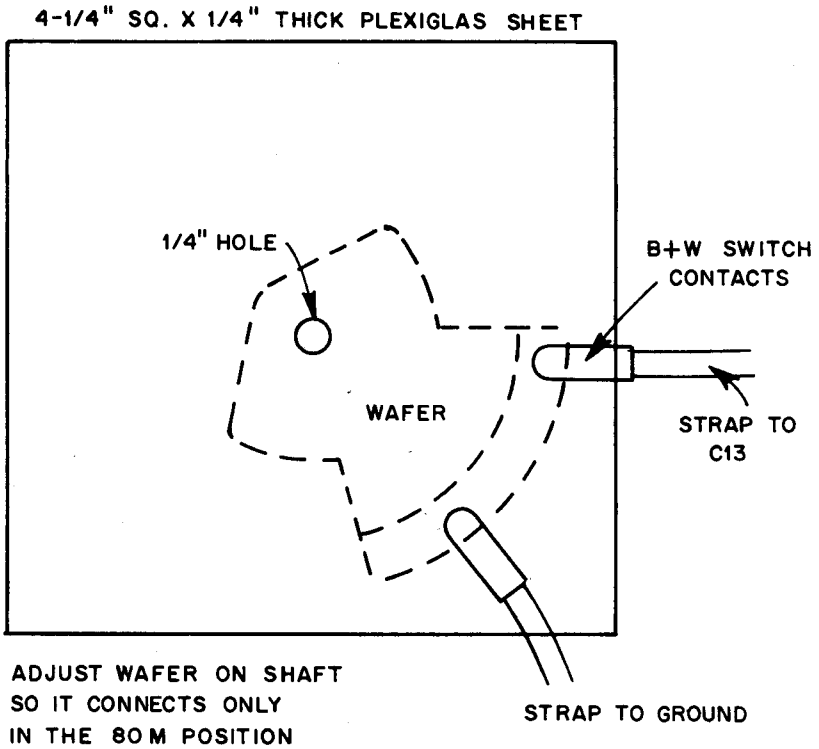


(A)



MATERIAL: ¼" ALUM. PLATE CUT TO SHAPE OF SWITCH WAFER

(B)



(C)

Fig. 68 — Details of the homemade switch used for S2C. At A is a full-size template of the wafer. Material is double-sided circuit board. Remove all copper but that indicated by the shaded area; the pattern should be the same on each side of the board. The aluminum piece that mates the switch wafer to the band-switch shaft is shown at B. At C, the entire switch is assembled on a Plexiglas sheet.

A 160- to 10-Meter Amplifier Using the 3CX1200A7

Billed as a replacement for the glass 3-1000Z, the EIMAC 3CX1200A7 metal/-ceramic triode is the basis of the 160- to 10-meter amplifier described here and shown in Figs 69 through 78. The amplifier will produce 1500 W output for about 100 W drive, making it a natural companion for today's solid-state transceivers. Dick Stevens, W1QWJ, designed and built this project.

The 3CX1200A7 requires a higher plate voltage than other ceramic transmitting tubes. In this case, the design is for 3500 V at full load. The amplifier will, however, still produce 1000 W output with 2500 V on the plate. A high-voltage power supply design is not included with this writeup. This amplifier was used with the power supply described earlier in this chapter along with a 160- to 10-meter 8877 amplifier. The high-voltage supply was modified slightly for use with this amplifier: C1 is increased to 200 μF, and R1 is changed to 1.5 kΩ to allow a longer charging time for C2. Another suitable high-voltage power supply design appears in Chapter 27.

A large volume of air is required to adequately cool the 3CX1200A7. Use of

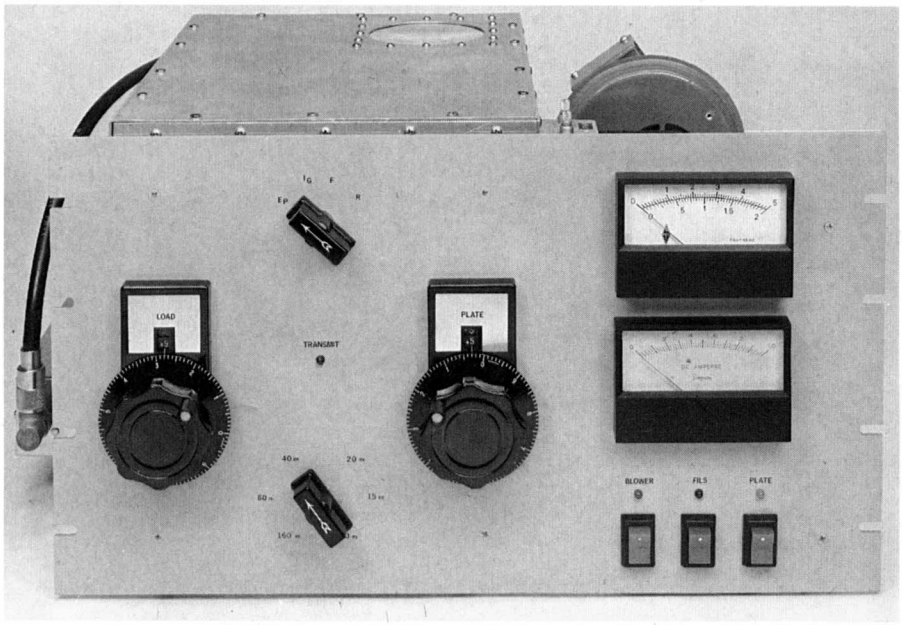


Fig 69—The 3CX1200A7 160- to 10-meter amplifier is built behind a standard 19 × 10½-inch rack panel. Vernier drives are used to control the loading and tuning capacitors. The top meter can be switched to read plate voltage, grid current, forward power and reflected power. (The meter switch is above the LOAD and PLATE dial drives.) The bottom meter is dedicated to plate current. An external low-pass filter is mounted on the left side of the chassis.

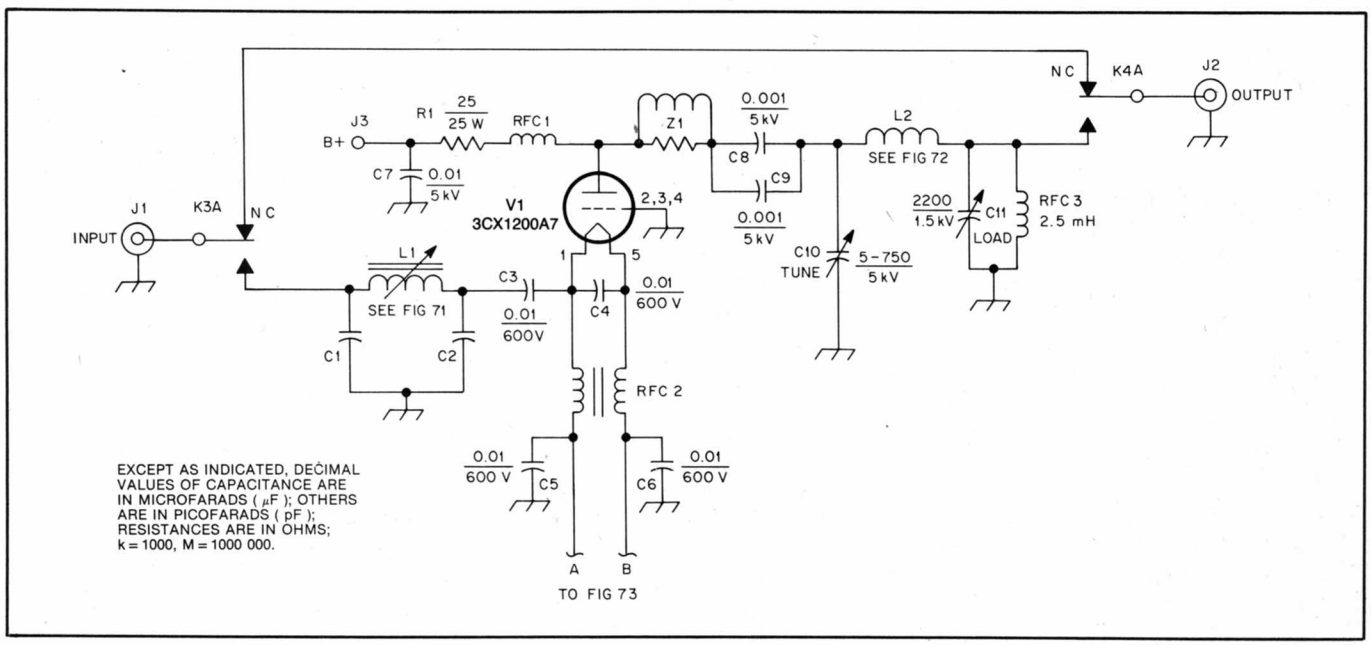
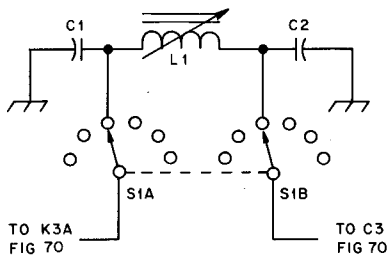


Fig 70—Schematic diagram of the 3CX1200A7 amplifier RF deck. Details of the input and plate-tank circuits are shown in Figs 71 and 72.

C1, C2—See Fig 71.
C3, C4—0.01-μF, 600-V mica capacitor.
C5, C6—0.01-μF, 600-V disc-ceramic capacitor.
C7—0.01-μF, 6-kV disc-ceramic capacitor.
C8, C9—0.001-μF, 10-kV RF-type doorknob capacitor.
C10—5 to 750-pF, 5-kV vacuum-variable capacitor.
C11—2200-pF, 1.5-kV air-variable capacitor.
J1, J2—UHF female chassis-mount connector.
J3—High-voltage connector (Millen 37001 or equiv).
K3, K4—See Fig 73.
L1—Input pi-network tunable coil. See Fig 71 for details.
L2—Plate-tank coil. See Fig 72 for details.
RFC1—90-μH, 1-A RF choke (Hammond 1521 or equiv).
RFC2—Bifilar wound 30-A filament choke, 28 bifilar turns no. 10 enam wire on a ½-in. diam × 7½-in. long ferrite core (Peter W. Dahl Co).
RFC3—2.5 mH RF choke (Millen 4537 or equiv).
Z1—Parasitic suppresser, four 220-Ω, 2-W metal-film resistors in parallel, mounted on a 5-inch long, ½-inch wide copper strap bent in a U shape.



	Q = 4			Q = 2		
Band	C1 (pF)	C2 (pF)	L1 (μH)	C1 (pF)	C2 (pF)	L1 (μH)
160	3300	3100	3.53	1608	1608	4.9
80	1700	1670	1.90	782	782	2.4
40	900	840	0.96	402	402	1.2
20	440	417	0.47	204	204	0.62
15	300	275	0.32	135	135	0.41
10	220	205	0.23	101	101	0.30

Fig 71—Details of the 3CX1200A7 amplifier input circuit. Component values are shown for Q = 4 and Q = 2. The amplifier was built using the values for Q = 4 (see text).

C1, C2—500-V silver-mica capacitors. See table for values.
L1—The coils for each band are wound on JW Miller 42A000CBI tunable ceramic coil forms (3/8-inch diam with red core). The number of turns required for each band:
10 meters—4 turns no. 22 wire spaced to occupy 3/8 in.
15 meters—6 turns no. 22 wire spaced to occupy ½ in.
20 meters—7 turns no. 22 wire spaced to occupy ½ in.
40 meters—9 turns no. 22 wire spaced to occupy ½ in.
80 meters—11 turns no. 22 wire close wound.
160 meters—20 turns no. 24 wire close wound.
S1—Double wafer, 6-position ceramic rotary switch with 60° indexing to match plate-tank bandswitch S2 (Centralab 2551 or equiv).

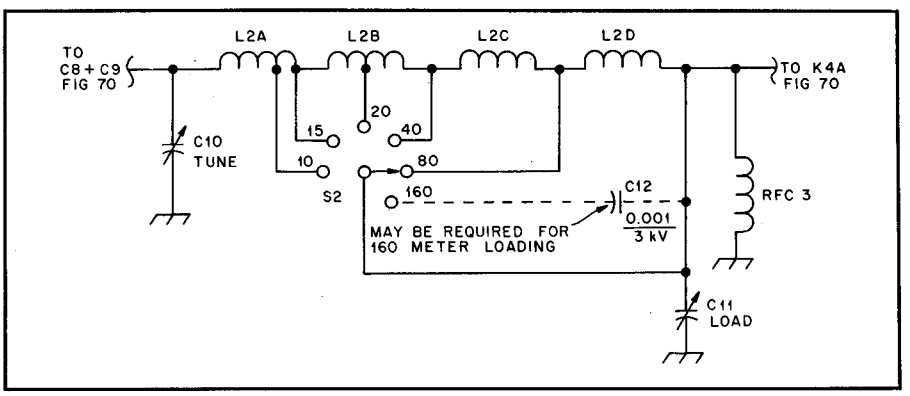


Fig 72—Details of the plate-tank circuit for the 3CX1200A7 amplifier. See Fig 70 for the rest of the circuit.

C10, C11—See Fig 70.
L2A—5 turns of ¼-inch diam copper tubing, 2¼ inches ID, 2½ inches long. See text. Tap at 4 turns for 10 meters. Tap at junction of L2A and L2B for 15 meters.
L2B—6¼ turns of B&W 2404T coil stock. Tap at 3 turns for 20 meters. Tap at junction of L2B and L2C for 40 meters.
L2C—6½ turns of B&W 2406T coil stock. Tap at junction of L2C and L2D for 80 meters.
L2D—10 turns of B&W 2408T coil stock. For 160 meters, use L2A, L2B, L2C and L2D.
RFC3—See Fig 70.
S2—Six position, one section, high-power ceramic RF rotary switch with nonshorting contacts and 60° indexing (Radio Switch Corp Model 86 or equiv).

the proper EIMAC air system socket (part no. SK410) and chimney (part no. SK436) is essential. The blower is a Dayton 4C440, rated at 60 CFM.

This project makes extensive use of parts purchased at flea markets and from surplus dealers. Although most components could be purchased new (at considerable expense), there are many good parts available surplus. The builder is encouraged to modify the design shown here when possible to make use of whatever surplus parts are available.

RF Circuits

Fig 70 is a schematic of the amplifier RF circuitry. For clarity, some details of the input and output circuits are omitted—these details are shown in Figs 71 and 72.

Details of the tuned input circuit are shown in Fig 71. Individual pi networks are used for each band. A tunable coil and two fixed capacitors are used for each band. These circuits are designed for a Q of 4, based on EIMAC's recommendation. Tubes requiring high values of grid drive require a higher Q than the usual 2 to prevent flattopping. Tuning of the input circuits is sharp, but if they are adjusted for an SWR of 1:1 at the center of each band, the SWR at the band edges is less than 1.5:1.

Unfortunately, you won't be able to "fudge" the 10-meter input circuit to reach 12 meters—the Q is too high. Component values are given for input networks with a Q of 2 for those builders wishing to reach 12 meters.

The amplifier plate tank circuit is a standard pi network with a calculated Q of 10. Details are shown in Fig 72. Use of a vacuum variable (C10) for the tuning capacitor makes it easy to get a reasonable Q at 160 and 10 meters. The 3CX1200A7 has a high internal capacitance: tube capacitance and stray circuit capacitance are almost enough to resonate the plate circuit at 10 meters. The minimum capacitance of an air variable suitable for tuning on 160 meters is too great to allow a reasonable Q on 10 meters. So, the vacuum variable, with its low minimum capacitance, is ideal for this application. An air-variable capacitor (C11) is used for loading. As shown in Fig 72, an additional 1000-pF fixed capacitor (C12) may be switched in if more loading range is needed for 160 meters.

The location of RFC1 differs from many other designs. Normally, the plate RF choke is connected to the junction of the parasitic suppressor (Z1) and plate blocking capacitor (C8 and C9). In this case, a low-frequency parasitic was noticed during testing, and moving RFC1 to the position shown corrected this problem.

Switches for the input (S1) and output (S2) circuits are connected by a chain drive so only one front-panel bandswitch control is needed. S1 and S2 *must* have the same indexing. All of the parts necessary for making the chain drive arrangement are available from Small Parts, Inc (see Chapter 35).

Metering and Control Circuits

Control and metering circuits are shown in Figs 73 through 75. Circuitry is included to prevent amplifier operation without plate voltage, and filament inrush protection is also provided. No ALC arrangement is used because modern transceivers will not overdrive the amplifier. Metering includes grid current, plate current, plate voltage and forward and reverse power.

Refer to Fig 73. Closing S1 starts the blower and lights DS1. Closing S2 applies 120 V to T2 through R3, the inrush-current-limiting resistor. Simultaneously, C1 charges through R2, and after a second or so K1 operates and contacts K1A short out R3, applying full primary voltage to T2. K1B contacts cause DS2 to light, showing that the filament inrush protection has functioned. Closing S2 also applies 120 V

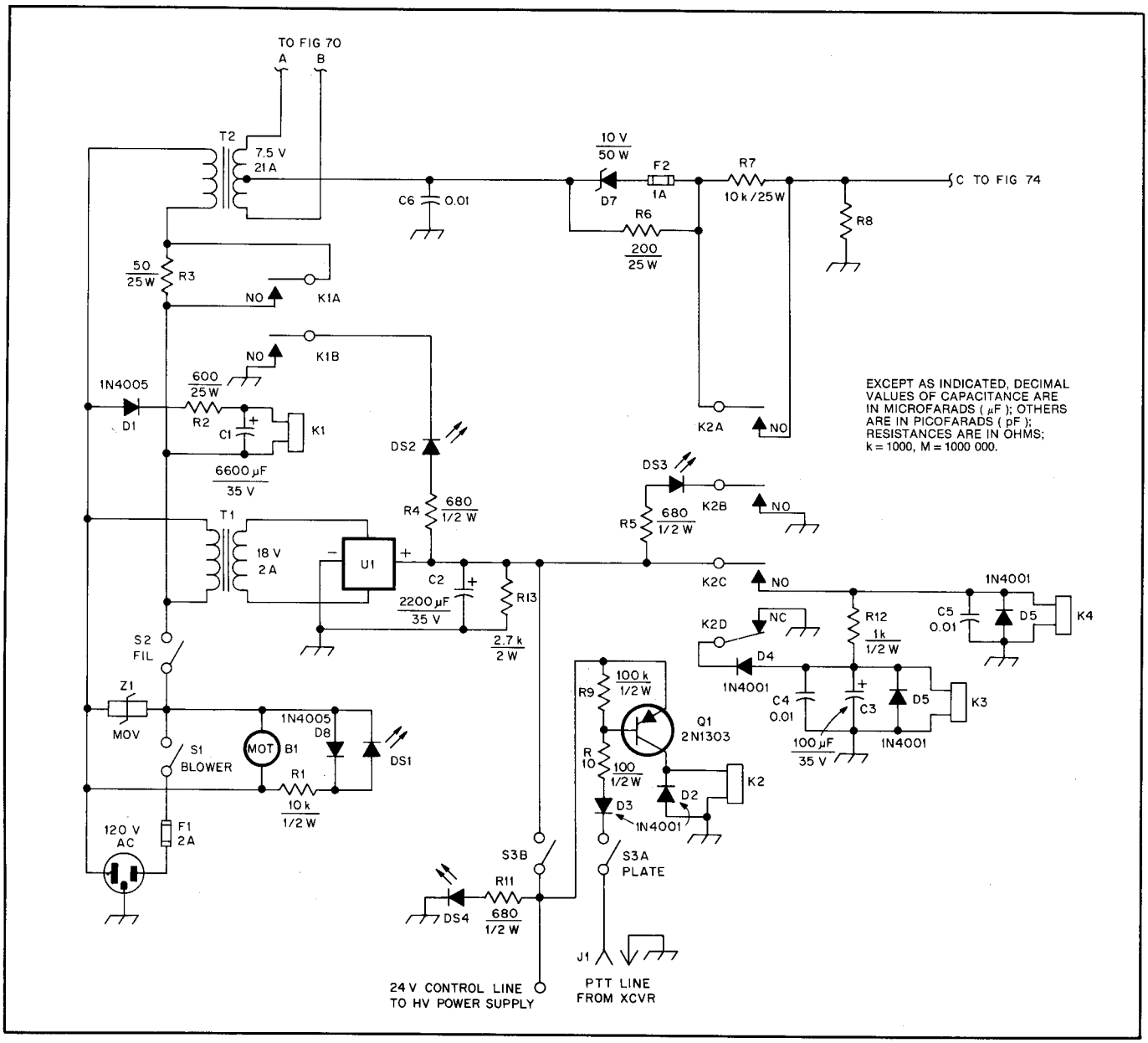


Fig 73—Details of the control circuitry for the 3CX1200A7 amplifier. Capacitors are disc-ceramic, 50-V types unless noted. Capacitors marked with polarity are electrolytic.

B1—60 CFM blower (Dayton 4C440 or equiv).
C1—6600-μF, 35-V electrolytic made from two 3300-μF, 35-V capacitors in parallel.
D1, D8—600-PIV, 1-A diode (1N4005).
D2-D6—50-PIV, 1-A diode (1N4001).
D7—10-V, 50-W Zener diode (1N2808 or equiv).
DS1-DS4—LED.
J1—Phono jack.
K1—DPDT relay with 10-A contacts and 12-V dc coil.
K2—4PDT relay with 3-A contacts and 24-V dc coil.
K3—RF input relay (see Fig 70). SPST relay with 3-A contacts and 24-V dc coil.
K4—Antenna relay (see Fig 70). SPST relay with 10-A contacts and 24-V dc coil. Dow-Key antenna relay preferred; must be able to handle 1.5 kW of RF.
R8—Grid-current meter shunt. Value depends on meter movement used. See text.
S1, S2—SPST switch.
S3—DPDT switch.
T1—Control circuit transformer. Primary, 120 V; secondary, 18 V at 2 A.
T2—Filament transformer. Primary, 120 V; secondary, 7.5 V at 21 A (Peter W. Dahl Co).
U1—100-PIV, 1.5-A bridge rectifier.
Z1—130-V metal-oxide varistor.

to T1. T1 and related components supply 24 V dc for other control circuits.

Closing S3 sends 24 V dc to the high-voltage power supply. The high-voltage supply is activated by a 24-V dc relay in the primary. DS3 lights when S3 is closed. You may choose a different method of activating the high-voltage supply, depending on your individual needs.

Q1 is the amplifier keying transistor. Many modern transceivers have amplifier keying circuits with insufficient current and/or voltage ratings to close a relay coil. They can, however, key Q1 which in turn keys the relays in the amplifier. When Q1 conducts, K2 operates and completes several functions. K2A shorts out R7, which changes the tube bias from cutoff to operating bias. DS3 lights to show that the tube is ready to operate. K2C activates K3 and K4, the antenna relays. K4, the output relay, closes immediately. There is a slight delay in the closure of K3, caused by R12 and C3, to prevent hot switching K4. When the amplifier is unkeyed to return to receive, K2D discharges C3 so that there is no additional delay as K3 returns to the receive position.

Operating bias is provided by D7. F2 protects the grid from excessive current. R8 is a grid milliammeter shunt. Its exact value depends on the meter used.

This amplifier includes metering for plate current, grid current, plate voltage, forward power and reverse power. See Fig 74. M2 is a dedicated plate-current meter. M1

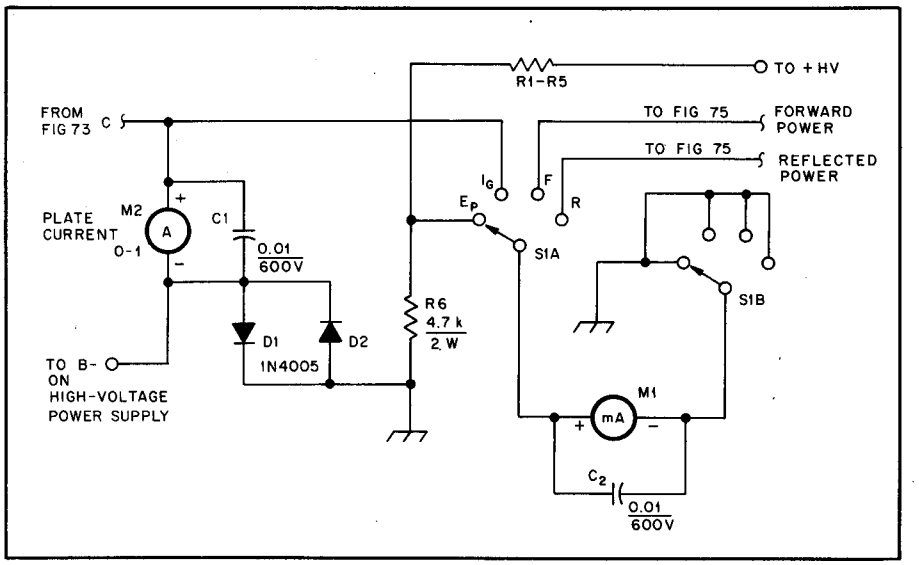


Fig 74—Schematic of the metering circuitry for the 3CX1200A7 amplifier. Note that S1B may be left out and the negative lead from M1 may be returned directly to ground.

M1—0 to 1-mA meter movement with scales to read 0-2 and 0-5. See text.
M2—0 to 1 A meter.
R1-R5—HV meter multiplier, 5 MΩ at 10 W. Made from five 1-MΩ, 2-W (2% tolerance) resistors in series.
S1—2-pole, 4-position rotary switch.

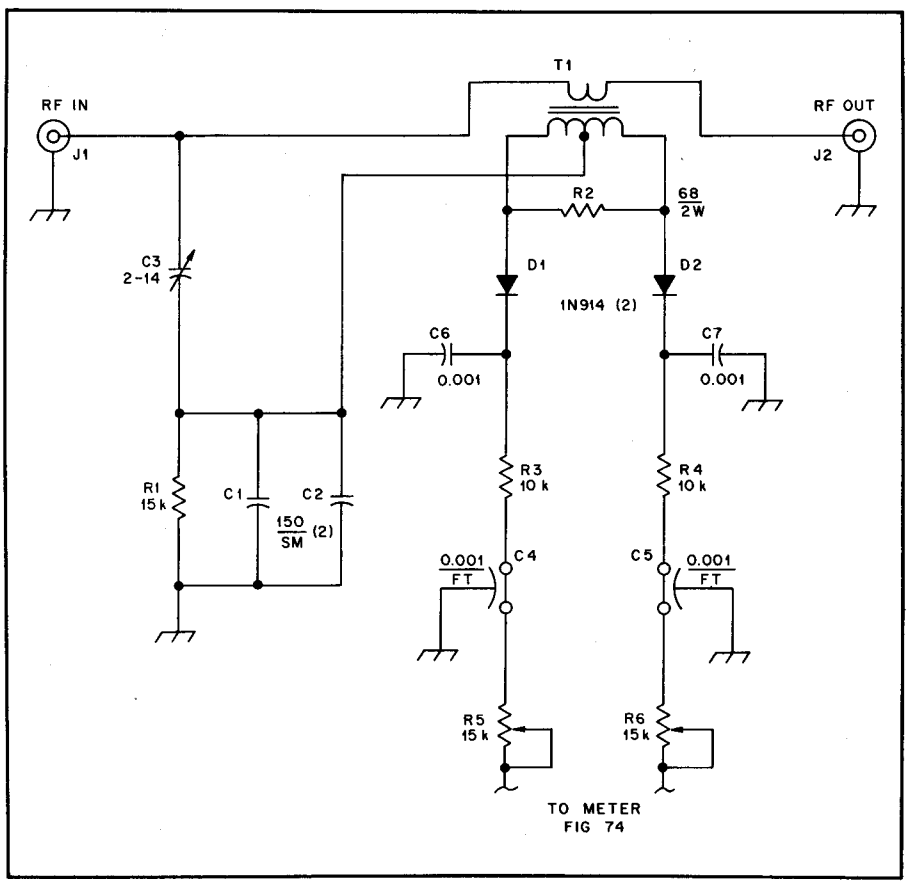


Fig 75—Schematic of the wattmeter circuitry for the 3CX1200A7 amplifier.

C1, C2—150-pF silver-mica capacitor.
C3—Miniature ceramic or air trimmer, approx 2-14 pF.
J1, J2—SO-239 chassis-mount connector.
T1—Secondary: 20 turns no. 22 enam on Amidon T-50-2 core, center tapped. Primary: Section of RG-8 through center of secondary core; connect the RG-8 center conductor between the center pins of J1 and J2. Ground the shield.

is a 0-1 mA movement with scales that read 0-2 and 0-5. S1 is used to switch in the appropriate shunt or meter multiplier resistor. Depending on switch position, M1 reads 0-500 mA grid current, 0-5 kV plate voltage, 0-2000 W forward power and 0-200 W reflected power. R6 prevents the voltage at the end of multiplier string R1-R5 from going to supply voltage when S1 is set to positions other than plate voltage. Note that S1 can be a single-wafer switch. S1B is not needed—the negative end of M1 may be grounded and S1B eliminated. Fig 75 shows the wattmeter. This circuit is similar to many others that have appeared over the years.

Construction

Figs 76 and 77 show the amplifier with the covers removed. Detailed dimensions are not given because many of the parts used are surplus. It would be difficult to duplicate this amplifier exactly, so you should consider the information presented here as guidelines, rather than as "cookbook" directions.

The input circuit is built on a 3 × 17 × 4-inch (HWD) chassis (Bud AC-432) that runs along the back of the amplifier chassis assembly. The 3CX1200A7 socket is mounted to this chassis, and underneath are the filament choke, input bandswitch, individual pi-network input circuits for each band, coupling and bypass capacitors, and the input relay and associated circuitry. Originally, the filament transformer was mounted on this chassis as well, but it was moved to cure an instability problem. (The metal case of the filament transformer did not provide a good shield). B1 blows air into the sealed input-circuit compartment, and air is exhausted into the output-circuit compartment.

The filament transformer, control circuits and bias components are built in a 3 × 9.25 × 7-inch (HWD) chassis that is bolted to the input chassis. (This is a standard Bud AC-408 chassis shortened to 9.25 inches.)

Output-circuit components, including the tuning and loading capacitors, tank coil and bandswitch, are mounted on a piece of 1/8-inch aluminum sheet. A heavy copper strap is used for grounding the tuning and loading capacitors. Use of this strap is necessary to prevent ground-loop currents.

Four separate pieces make up the plate-tank coil. See Figs 72 and 76 for details. A length of ¼-inch diameter soft-drawn copper tubing is the basis for the 10-meter coil. Clean the tubing well and wind 6 turns on a 1¾-inch diameter form. (This is one more turn than needed, but gives some extra material to work with.) Flatten one end of the tubing and drill it to clear a no. 6-32 screw. Remove the excess turn, flatten the other end and drill it to pass a no. 6-32 screw. Spread or compress the coil so that there are 2½ inches between the centers of the holes drilled in the ends of

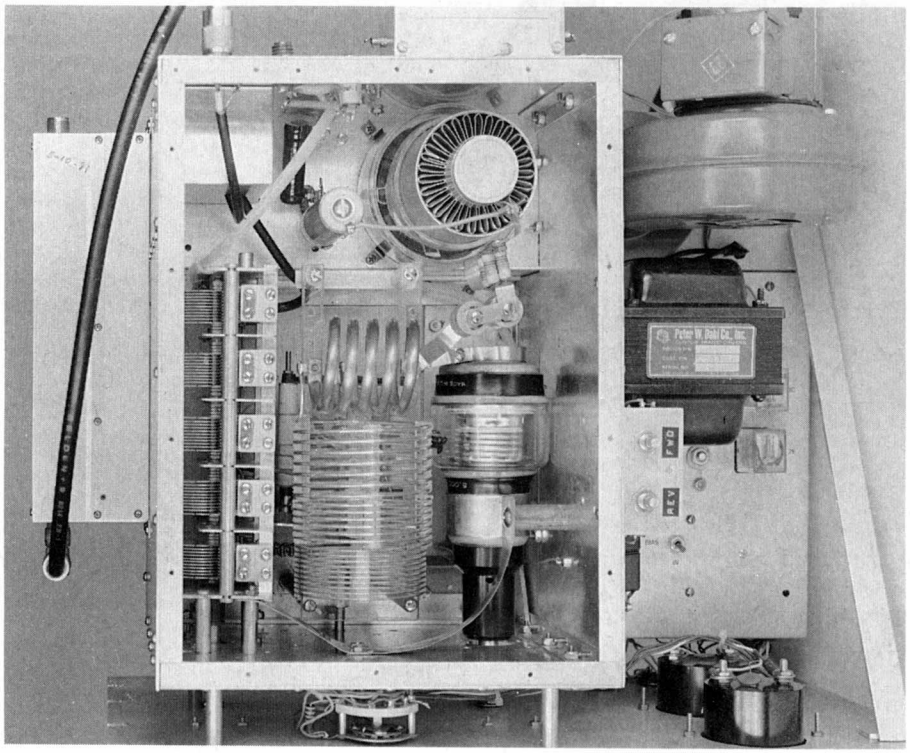


Fig 76—Top view of the 3CX1200A7 amplifier with the cover removed. The blower, at the right rear, is bolted to the input chassis that runs along the rear of the amplifier assembly. The filament transformer is mounted in front of the blower, on the chassis that holds the control circuits. K1 and K2 are mounted in sockets to the right of the filament transformer. The wattmeter adjustment potentiometers (R5 and R6, Fig 75) are mounted on a bracket on the side of the plate-circuit enclosure near the filament transformer. The plate-current meter and multimeter are mounted on the front panel (lower right corner of photo), and the multimeter rotary switch is mounted to the front panel in front of the plate-circuit enclosure. The 3CX1200A7 is mounted on the input-circuit chassis at the right rear of the plate circuit enclosure. High-voltage wiring and bypass capacitors, and the RF choke, are to the left of the tube. The Minibox in the left rear corner of the plate-circuit compartment houses K4, the output relay. The vacuum-variable tuning capacitor is mounted at the right front of the plate compartment, and the loading capacitor is at the left front. The plate-coil assembly and plate-circuit bandswitch (under the plate coil) are mounted between the two capacitors.

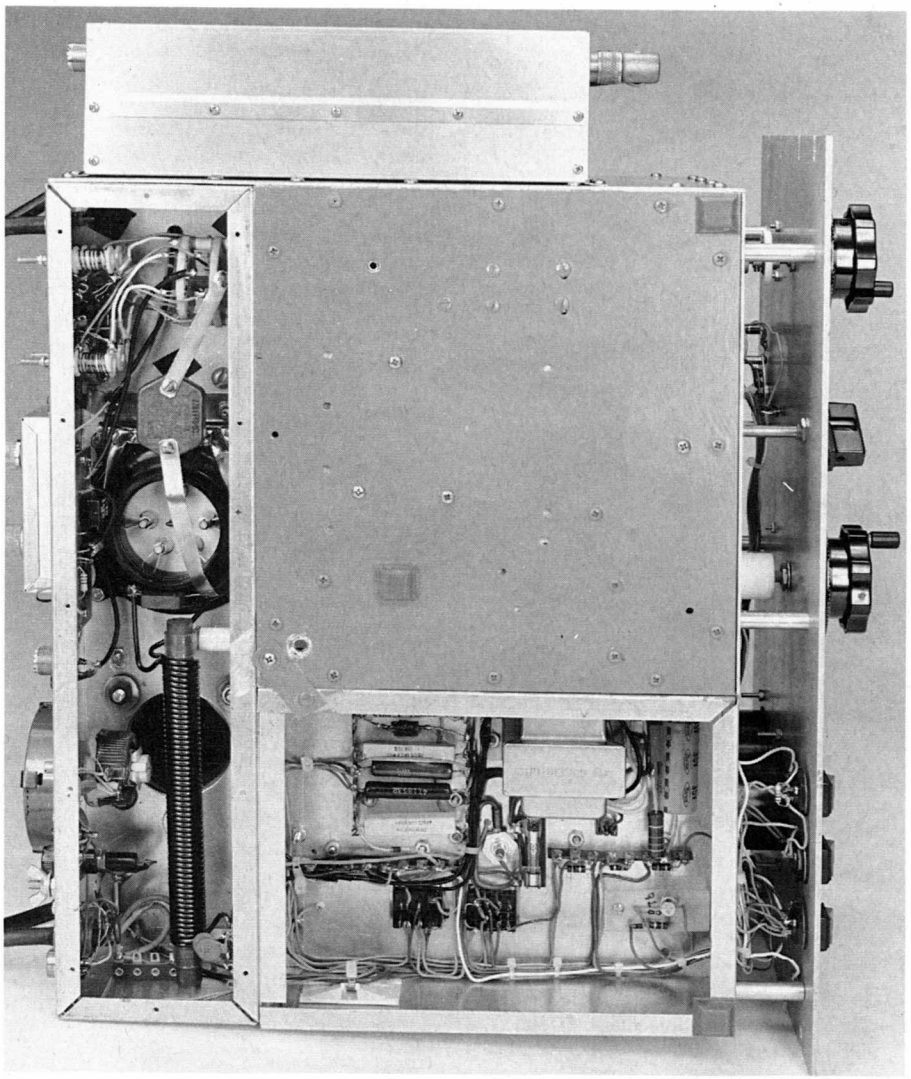


Fig 77—Bottom view of the 3CX1200A7 amplifier with the covers removed. The amplifier chassis assembly consists of three parts: (1) the input chassis (left side of photo) runs the entire width of the amplifier; (2) the control circuit chassis (lower right); and (3) the plate compartment (upper right) built on an aluminum sheet. The tuned input circuits are visible in the input chassis, above the tube socket. The pi networks are built on an unetched piece of circuit board material, with the coil adjustment shafts protruding through the rear panel. The input bandswitch is mounted to the opposite chassis wall, with its shaft protruding into the plate-circuit compartment. Below the tube socket is the filament choke. A small circuit board bolted to the rear wall to the left of the tube socket holds the input relay and associated components. In the control-circuit chassis, most components are mounted on terminal strips. K1 and K2 are mounted in sockets in the lower center of the chassis. Q1 and associated parts are mounted on a small circuit board in the lower right corner.

the coil. The finished coil is 5 turns, spaced 2½ inches.

A 2-7/8 × 8¼-inch piece of ¼-inch-thick Plexiglas® serves as the main plate-tank coil support. Drill a mounting hole in each corner of the Plexiglas sheet, ¼ inch in from the ends. Drill two holes for the 10-meter coil 1-5/8 inch in from one end. Mount the 10-meter coil above the Plexiglas sheet on 3/8-inch spacers.

Next, cut three pieces of B&W coil stock. You'll need 6¼ turns of 2404T, 6½ turns of 2406T and 10 turns of 2408T. Slide the 2404T onto the Plexiglas support, followed by the 2406T and then the 2408T. Using a thin piece of brass shim stock, connect one end of the 2404T to one of the mounting screws for the 10-meter coil. Using more shim stock to make a good mechanical bond, splice the other end of the 2404T to the 2406T, and the 2406T to the 2408T. Solder all connections. The free end of the 2408T goes to the loading capacitor.

The output-circuit shield is made of sheet aluminum and angle stock. The top has a screened hole for hot air exhaust.

K4, the output antenna relay, is in the Minibox mounted to the inside rear wall of the output compartment, directly behind the loading capacitor. The wattmeter RF-sensing circuitry is inside the Minibox mounted on the outside of the back panel, near the tube.

Problem Areas

During original tests, the amplifier operated very poorly above 20 meters. It had severe LF and VHF parasitics, and none of the common cures worked. By accident, it was found that the case of the filament transformer was hot with RF energy, and in fact an arc could be drawn from the transformer mounting bolts. An NE2 neon lamp, mounted on an insulated rod and placed near the tube or filament transformer, glowed bright purple. (Normally, the neon lamp glows orange in the presence of HF energy. If it glows purple, VHF energy is present.) Removing the filament transformer from the shielded plate compartment cured the VHF parasitic problem, but there was still a trace of a low-frequency parasitic. Moving the plate RF choke (RFC1) to the position shown in Fig 70 cured this problem.

Table 1

Typical Operating Conditions for the 3CX1200A7 Amplifier

Plate Voltage	3500 V
Plate Current	800 mA
Grid Current	180 mA
Power Output	1500 W
Drive Power	100 W
Input SWR	<1.5:1

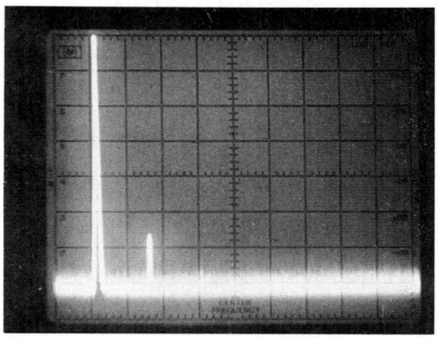


Fig 78—Spectral photograph of the 3CX1200A7 amplifier operating through the low-pass filter. Power output is 1500 W at 14 MHz. Each horizontal division is 10 MHz; each vertical division is 10 dB. All harmonics and spurious emissions are at least 56 dB below peak output.

Tune-Up

Check the high-voltage supply for proper operation before connecting it to the RF deck. Check all circuit paths in the power supply and RF deck for possible short circuits. Verify the operation of all control circuits with the high-voltage off and with the tube removed from the socket. When everything works, place the tube in the circuit and apply power to the blower, filament transformer and control circuitry. Measure the filament voltage at the tube socket; it should be 7.5 V. If all is well, remove power from the RF deck and install the covers. Connect the high-voltage supply. Connect an exciter capable of delivering about 100 W to the input through a wattmeter and connect the amplifier output to a suitable dummy load through a second wattmeter.

Close the the BLOWER and FILS switches. The blower will start and filament power will be applied. The BLOWER and FILS lamps will light. Close the PLATE switch, and the high-voltage will come on. Plate voltage should register with M1 in the E_P position. Press the transceiver PTT switch. M2 should indicate about 150 mA resting plate current.

Apply about 10-W drive and adjust the slugs of the coils in the input pi networks for lowest SWR at the center of each band. Adjust the TUNE and LOAD controls for maximum output. Gradually increase drive until the power output reaches 1500 W. With 3500 V on the plate, grid current should be about 200 mA, and plate current should be about 800 mA. Recheck the input SWR on each band with the amplifier running at full output.

Table 1 shows the operating parameters for this amplifier. Although it has no problem meeting FCC specifications for spectral purity, a B&W low-pass filter is bolted to the side of the plate-tank compartment for added harmonic suppression. Fig 78 shows the spectral output of the amplifier with the low-pass filter.